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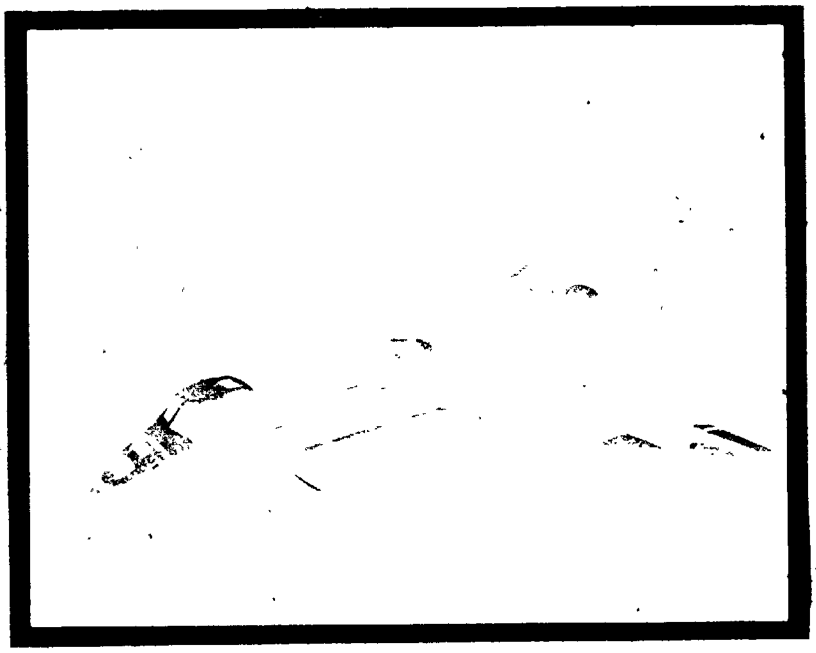
SENSING and DATA ACQUISITION



OAST Summer Workshop

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National Aeronautics and Space Administration
Office of Aeronautics and Space Technology and Old Dominion University

Vol [illegible] of X

NOTICE

The results of the OAST Space Technology Workshop which was held at Madison College, Harrisonburg, Virginia, August 3 - 15, 1975 are contained in the following reports:

EXECUTIVE SUMMARY	
VOL I	DATA PROCESSING AND TRANSFER
VOL II	SENSING AND DATA ACQUISITION
VOL III	NAVIGATION, GUIDANCE, AND CONTROL
VOL IV	POWER
VOL V	PROPULSION
VOL VI	STRUCTURE AND DYNAMICS
VOL VII	MATERIALS
VOL VIII	THERMAL CONTROL
VOL IX	ENTRY
VOL X	BASIC RESEARCH
VOL XI	LIFE SUPPORT

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ATTN: 418/CHARLES I. TYNAN, JR.

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Office of Aeronautics and Space Technology

Summer Workshop

August 3 through 16, 1975

Conducted at Madison College, Harrisonburg, Virginia

Final Report

SENSING AND DATA ACQUISITIONS PANEL

Volume II of XI

OAST Space Technology Workshop

SENSING AND DATA ACQUISITION PANEL

Robert N. Parker
CHAIRMAN
LANGLEY RESEARCH CENTER

MEMBERS:

A. DEEPAK.......................................OLD DOMINION UNIVERSITY

R. V. HESS....................................LANGLEY RESEARCH CENTER

P. R. MALONEY..................................JOHNSON SPACE CENTER

H. G. McCAIN............................GODDARD SPACE FLIGHT CENTER

S. L. OCHELTREE.............................LANGLEY RESEARCH CENTER

W. T. POWERS..........................MARSHALL SPACE FLIGHT CENTER

B. RUBIN..OAST

H. G. TROSTLE.............................JET PROPULSION LABORATORY

J. VORREITER..OAST

COLLABORATOR:

SURENDRA N. TIWARI
ASSOCIATE PROFESSOR
MECHANICAL ENGINEERING
& MECHANICS
OLD DOMINION UNIVERSITY

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SUMMARY

The Sensing and Data Acquisition Working Group followed the basic guidelines proposed by the OAST for identifying the mission and opportunity driven technology requirements and candidate space experiments. The major thrusts set out by the group were as follows: (1) provide a 10-fold increase in mission output through improved sensing accuracy, resolution, and spectral range by 1985, (2) reduce information system cost by 1 to 2 orders of magnitude through extensive integration of sensor and on-board processing technology by 1985, and (3) provide the capability for near real time, low cost, global surveys through multipurpose, all weather active/passive microwave systems by 1990. The relevance of these thrusts was demonstrated by identifying various payload experiments and through several examples of payload/major thrusts relationships. The payloads were the primary product of the workshop and were responsive to "user" inputs as well as possible national space themes contained in the recently completed NASA study, Outlook for Space. It is suggested that the workshop results should be considered as the beginning of a process to relate advanced technology to potential shuttle pay loads.

INTRODUCTION

This is the final report of the Sensing and Data Acquisition Working Group assembled under the auspices of the OAST Space Technology Workshop. The Sensing and Data Acquisition Working Group (SDAWG) met at Madison College, Harrisonburg, Virginia, August 4-15, 1975.

The objective of the Workshop, as understood by the SDAWG, can be characterized as: (1) identification and selection of advanced technology requirements associated with sensing and data acquisition systems, (2) identification of advanced sensing system payloads which would benefit from the use of shuttle in demonstrating technology readiness, and (3) review and updating of a sensing and data acquisition technology development "road map". The approach taken by the SDAWG was to review and consolidate inputs, select key technology requirements, define space technology payloads, and review and update road map. Inputs were obtained from a number of sources such as Advanced Technology Requirements (all NASA centers), Inventory of Sensors (JPL), Outlook for Space Report, User Requirements (NASA HDQRS), Mission Models, and Shuttle Systems Information.

The complete report is divided into two parts. The first part (Report I) covers the synthesis of payloads and associated advanced technology requirements. The advanced technology requirements of interest to users, but not associated with the specific payloads, are discussed in Report II. Each report starts with introductory comments and ends with concluding remarks.

SENSING & DATA ACQUISITION WORKING GROUP

REPORT I

SHUTTLE PAYLOADS AND RELATED ADVANCED TECHNOLOGY REQUIREMENTS

- INDEX -

INDEX (cont'd.)

SECTION A: GENERAL

A-1 INTRODUCTION

This part (Report I) of the total report covers the synthesis of payloads and associated advanced technology requirements defined by the Sensing and Data Acquisition Working Group of the OAST Space Technology Workshop. The payloads are the primary product of the workshop and are responsive to "user" inputs (meaning the NASA program offices as users of OAST technology), as well as possible national space themes contained in the recently completed NASA study, Outlook for Space. The advanced technology requirements of interest to the users, but not associated with the specific payloads defined in Report I, are discussed in Report II of the working group total report.

In defining payloads within the context of "user" inputs and the Outlook for Space themes, it became apparent that multiple concepts of payloads were needed. Some members of the working group saw payloads as a component level evaluation. Others saw payloads as a system level requirement, allowing the various components to interact. Still others saw payloads as an advanced system, functionally interacting with the real environment and performing useful measurements. The working group endorsed all three concepts of payloads and, in doing so, recognized that NASA payloads were being defined, requiring a close partnership between OAST and the "user" program offices.

During the course of the workshop, all working groups were asked to define "major thrusts" which best described the significant goals the discipline should be driven towards. The major thrusts for the Sensing and Data Acquisition discipline are stated in section A-3 and evaluated in the Conclusions, Section G.

The working group output is by no means an exhaustive treatment of the Sensing and Data Acquisition discipline. Further expansion of the payloads is also possible. However, the payloads selected are considered to represent an effective blend of advanced technology thrusts, most having multi-user impact.

A-2 SENSING AND DATA ACQUISITION MAJOR THRUSTS

1. Provide a 10 fold increase in mission output through improved sensing accuracy, resolution and spectral range by 1985.

2. Reduce information system cost by 1 to 2 orders of magnitude through extensive integration of sensor and onboard processing technology by 1985.

3. Provide the capability for near real time, low cost, global surveys through multipurpose, all weather active/passive microwave systems by 1990.

A-3 OUTLOOK FOR SPACE THEME - Payload Correlation

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Sensing & Data Acquisition Payloads		Outlook for Space Themes: 1 FOOD	2 ENVIRONMENT	3 LIFE & PROPERTY	4 ENERGY	5 INFORMATION	6 COMMERCIAL	7 EARTH SCIENCE	8 UNIVERSE	9 MATTER	10 STARS	11 SOLAR SYST.	12 ORIGIN OF LIFE
B-1	Stratospheric Trace Gases		X					X					
B-2	Global Aerosols & Gases	X	X	X				X				X	
B-3	Laser Atmospheric Gases	X	X	X				X				X	
B-4	Earth's Energy Budget	X	X		X						X		
B-5	Atmospheric Transmission	X	X					X					
C-1	Coastal Zone & Land Resources	X	X	X								X	
D-1	Advanced Microwave Radiometer Systems		X										
D-2	Advanced Radar/Scatterometer Systems	X	X									X	
D-3	Advanced Meteorological Radar	X	X	X									
E-1	Large Deployable Microwave Antennas	X	X	X		X		X				X	
E-2	Radar Calibration System	X	X	X		X		X				X	
E-3	Submillimeter Wavelength Receivers		X	X				X				X	
E-4	Earth Viewing I R Components	X	X		X			X				X	
F-1	Extreme U V Astronomy								X	X	X	X	X
F-2	Column Density Monitor								X	X	X	X	
F-3	Advanced Technology Radiometer								X	X	X	X	

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A-4 USER REQUIREMENT - PAYLOAD CORRELATION

Index of User Requirements: Sensing and Data Acquisition

User		Requirement	Payload Index Number
Office of Applications	1.	Lasers, high power, space qualified, 5-10 year lifetime	B-3
	2.	Sensor platforms, ground-based, for position location	---
	3.	Accelerometers, space qualified, increased accuracy, gravity	---
	4.	Microwave measurement technology requirement	D-1, D-2, D-3, E-2
	5.	Air temperature sensor	B-4, D-1, D-3
	6.	Ocean surface evaporation rate monitor	B-4, D-1, D-3
	7.	Ocean current at-depth measuring device	---
	8.	Sub-ocean topography sensor	---
	9.	Earth gravity field measuring device	---
	10.	Continental location device (interferometry)	---
	11.	Microwave sensors calibration	E-2
	12.	Soil moisture profile measurement device	D-1
	13.	CCD imager-multi-spectral Earth observation	C-1
	14.	CCD data processor for Radar	D-2
	15.	Tornado detector-microwave	D-2
	16.	Rainfall, precipitation microwave measurement	D-3
	17.	Transmission/Absorption Atmospheric properties monitor	B-3, E-2

User	Requirement	Payload Index Number
	18. Lasers/lidars-near ground pollution	B-3
	19. Atmospheric contaminants monitor	B-1, B-2, B-3
	20. Spectrometer/Interferometer-Atmospheric pollution	B-3
	21. Water pollution Lidar System	C-1
	22. Cryo coolers	B-3, C-1
	23. Low-cost optical elements	---
	24. Detectors with response matched to molecular lines	B-3
	25. Atmospheric/Earth probes	B-1, B-3, C-1, D-2, D-3

Index of User Requirements: Sensing and Data Acquisition

User		Requirement	Payload Index Number
Office	1.	25-29th magnuitude star observer	---
of	2.	U. V. sensors for astronomy	C-1, F-1
Space	3.	1.0" x-ray imager	---
Sciences	4.	mass position, seperation detector	---
	5.	solar flux detector	B-4
	6.	mm. and submm. microwave detectors	D-1
	7.	I. R. sensors	B-5, C-1, F-3, B-1, B-3
	8.	I. R. heterodyne Spectrometer	B-1, B-3
	9.	Laser ranger, sounder, detectors	B-1, B-3
	10.	cryogenic coolers	B-3, C-1, F-3
	11.	Asteroid sampler, analyser, <u>in-situ</u>	---
	12.	Comet gas, dust, collector	---
	13.	Mars surface sampler	---
	14.	Venus camera	---
	15.	Chemical analyzer, <u>in-situ</u>	---
	16.	Age detector, <u>in-situ</u>	---
	17.	Launch vehicle system/component commonality	---
	18.	Geochemical analyzer, in-situ	---
	19.	Seismic, heat flow, chemical sensors/lunar	---
	20.	X-ray, x-ray spectrometer	---
	21.	radar altimeter, lunar	---
	22.	Laser altimeter	---
	23.	Laser ranger, earth to moon	---

Index of User Requirements: Sensing and Data Acquisition

User		Requirement	Payload Index Number
Office	1.	Gas analyzer-cabin	---
of	2.	Laser radar-docking	---
Manned	3.	Meteroid impact detector	---
Space	4.	Atmospheric leak detector	---
Flight	5.	Rapid turn-around reuasable vehicle monitor	---

SECTION B: ATMOSPHERIC SENSING PAYLOADS

B-1 STRATOSPHERIC TRACE GAS EFFECTS

Application

This payload experiment addresses problems that fall under the Outlook for Space theme Prediction and Protection of the Environment which deals with Stratospheric Changes and Effects. The payload will consist of advanced technology remote sensing systems employing limb scanning infrared radiometers, gas correlation filters and high resolution spectrometers. These systems will be designed to detect and measure the vertical distribution of trace gas constituents and vertical temperature profiles in the stratosphere. The trace gases of primary importance in this region of the atmosphere are ozone, CO_2, and those gases which interact with them, e. g., oxides of nitrogen (NO_x), water vapor, and halogen compounds (CCl_4, CH_3Cl, etc.) Next in importance is a group of pollutants such as SO_2, NH_3, CH_4, and HNO_3. Global measurements of these trace gases and vertical temperature profiles are needed to develop a fuller understanding of the effects of man and nature on (1) the dynamics of stratospheric ozone layer which shields us from harmful ultraviolet radiation and (2) the heat balance of the earth's atmosphere and its influence on world climate. Data from this and subsequent experiments will provide the essential input data needed to develop theoretical models of the atmosphere which will achieve this understanding. In addition, this experiment will provide space flight demonstration of these advanced technology sensing systems.

Payload Description

This payload will consist of a group of advanced technology remote sensing instruments. Each instrument will be tailored to maximize its sensitivity to a single gas or particular group of trace gases. The most attractive instrument concepts considered for this payload fall into two classes of limb measurements. The first of these involved limb scanning instruments which may employ either gas or spectral filters to select and measure the thermal radiance of trace gas emission bands in the infrared. Once these thermal radiance data are obtained a sophisticated theoretical model is used to mathematically invert the data to obtain trace gas concentration and temperature profiles in the stratosphere. Instruments of this type have been tested on balloon flights and are now under development to measure O_3, H_2O, NO_2, HNO_3 concentrations and temperature profiles in the stratosphere. The second class of instruments involves a solar limb attenuation measurement which uses either gas or spectral filters to select and measure the infrared or ultraviolet absorption bands of trace gas species of interest. A gas-filter correlation instrument of this latter class is being analyzed for HCl and CH_4 measurements with a possible extension to "Freons" and HF.

Technology Requirements

The technology requirements for this payload include development of infrared detectors, non-radiative type coolers ($<100^{o}$K), high spectral and selectivity elements, gas filters, systems analyses and atmospheric modeling and ground truth sensing techniques.

Associated Mission Model

This payload supports the Outlook for Space system #2022 Stratospheric Monitoring System Development.

An improved limb viewing IR radiometer should be ready for a 1981 launch. This advanced technology demonstration flight would be in direct support of the Outlook for Space system #2022, "Stratospheric Monitoring System-Development", scheduled for launch in 1985.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Limb Viewing IR Radiometer — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Remote Sensing of Stratospheric Gases

3. OBJECTIVE/ADVANCEMENT REQUIRED: Higher Radiometric Sensitivity and Stability

Longer Mission Lifetime

Less Complex Scanning Mechanism

4. CURRENT STATE OF ART: Radiometric Sensitivity 70% required;

Radiometric Stability and Inflight Calibration Accuracy half of desired;

Lifetime 30-50% of that desired (2 yrs. desired) HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY This application requires a radiometer with narrow IFOVs (.25 to 1.0mr) capable of measuring the horizon radiance profile in selected IR spectral intervals from 5 to 20 m simultaneously with noise equivalent radiances (NENs) of 0.5 to 3.0×10^{-3} $w\text{-}m^{-2}$ -ster^{-1}. The radiometer must scan the IFOVs across the horizon and obtain data from 4 to 80 km's tangent height, as a minimum; or may utilize detector arrays which sample the horizon profile to the required vertical resolution and spacing. The radiometric sensitivity must also be keyed to high measurement accuracy, e.g. 0.1% precision, 1% accuracy, and ground equipment and procedures, sensor design, and inflight calibration techniques and mechanisms require further development to achieve this accuracy for long duration missions. Azimuth pointing capability is required to sample the atmosphere between orbital tracks. Geographical sampling is required at 400 to 600 km intervals (both latitude and longitude) whereas, typical orbital track separations are 2700 to 3200 km longitudinally. Present designs for such radiometers require further development and tests to assure achieving required performance goals. Alternate design concepts for these sensors also need to be explored, i.e. "staring" sensor using detector arrays with elemental readout logic, etc., in order to evaluate sensor design approaches for ultimate use in long term surveys.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Present systems designs for radiometers of required type are active scanners which require detectors cooled to 65K to 80K. More stable elevation scan systems and improved detectivities, and long duration coolers are required.

Testing of current systems has not been sufficient to explore the long term accuracy limitations of current designs.

Future monitoring needs for a given constituent, or photochemistry problem, can best be met by a single sensor sampling globally and over sufficient duration to determine variations.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Improved Limb Viewing IR Radiometer PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

Multi-channel inflight calibration techniques which match calibration levels to flight data ranges and having required accurac..
Higher sensitivity detectors for the 5-20 μm spectr.l range.
Long-life detector coolers with reasonable weight and/or power requirements.
Improved spectral filtering.
Improved out-of-field energy rejection.

9. POTENTIAL ALTERNATIVES:

Develop multi-constituent sensors for simultaneous measurement of related parameters using spectroscopic, interferometric, or laser approaches for measurement in solar occultation mode.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 176-10-31 has a low level of funding to support some studies relating to improvements of existing AAFE-LACATE sensor design (ac.ive scanning, azimuth pointing filter radiometer).

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

As discussed herein.

Improved spacecraft attitude rate measurement subsystems for correction of data for spacec.aft motion during data taking.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Limb Viewing IR Radiometer

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
A. Existing Design																			
1. Component SRT	x	x																	
2. Improved Design		x	x																
3. EM development			x	x															
B. New Design Approaches																			
1. Analysis & Tradeoffs	x	x																	
2. Design		x	x																
3. EM development				x	x														
APPLICATION																			
1. Preliminary Stratospheric survey–existing design							x	x											
2. Flight test new design								x											
3. Stratospheric Survey									x	x									

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			x			x												
NUMBER OF LAUNCHES							1	1	1									

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Stratospheric Research (Gases) PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Remote Sensing from Satellites

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased sensitivity detectors, very high resolution instrument techniques, advanced airborne detector cooling system technology.

4. CURRENT STATE OF ART: Present IR detectors provide a figure of merit (D^*) in the 10^9-10^{11} range. Instrumentation for satellite global monitoring is capable of $\sim$0.1 cm^{-1} spectral resolution. (Cont'd.) HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The sensitivity needed to study the gases of importance in future stratospheric research will require a one to two order of magnitude improvement in detector D^*. Also, the spectral resolution capability for an operational monitoring instrument (in the infrared) will need to be increased by about one order of magnitude to 0.01 cm^{-1}. Long lifetime detector cooling systems are required (2-3 years) with operating temperature capability in the range 30K or less. The most hopeful approach to meeting these cooling needs is the use of a closed cycle system such as the Vuilleumier (VM) cooler. A goal should be an operating power of no more than 60 watts.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Present systems for remote measurement of stratospheric parameters from satellites have been designed to measure the more obvious, less difficult trace gases (e.g., O_3, H_2O, CH_4, N_2O, NO_2, NO, HNO_3, and CO). However, as our knowledge of the stratosphere advances, there will be a need to measure some of the more subtle, but very important stratospheric gases. Some of these gases which are involved in the ozone depletion problem include Oh, HCL, HF, HB_r, Cl, ClO, CF_x, CL_y, (Freons), HO_2, Br_o, CH_3Br, CCl_4, and CH_3Cl. Others which are important from the standpoint of radiation balance and aerosol-gas chemistry include SO_2 and NH_3. All of these gases have concentrations in the parts per trillion range and most of them have not been observed in the stratosphere primarily because of limitations on instrumental sensitivity and spectral resolution. It may be necessary to cool not only the detectors, but also the instrument optics in order to achieve the desired sensitivity. Monitoring instruments for operational use are needed to measure long-term trends in these constituents.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Stratospheric Research (Gases)

7. TECHNOLOGY OPTIONS:

None.

8. TECHNICAL PROBLEMS:

It may not be feasible in the near future to construct a long lifetime cooling system which would operate at the desired temperatures and power levels, especially if optics must also be cooled.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Various programs are presently underway to measure stratospheric trace gases both in the limb emission and occultation modes. These include the Nimbus G SAMS and LIMS and the Atmospheric Explorer SAGE. In addition, improved LACATE and SAMS programs are in progress. These concepts could be extended and the efforts focused on achieving the desired technology advances. (cont'd.)

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ____________ PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. 2. 3. 4. 5.																			
APPLICATION 1. Design (Ph. C) 2. Devl/Fab (Ph. D) 3. Operations 4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Stratospheric Research (Gases) PAGE 4 OF 4

4. CURRENT STATE OF ART: (cont'd.)

and cooling is achieved presently by use of solid cryogen technology 65°K operation. Refrigerator systems are under development but present approaches create heavy power loads.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT: (cont'd.)

Also, various interferometer and spectrometer techniques have been used from balloons and aircraft. These approaches could be optimized for a specific gas or set of gases in designing a monitoring instrument. In the cooler area, various military and NASA programs are underway to advance the technology. These efforts will serve as base points in building future technology.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Optimize detectivity, response time and operating temperature.

4. CURRENT STATE OF ART: In the 1-14 micrometers range, II-VI and III-V semiconductor detectors have detectivities above 10^{10} cm-$Hz^{\frac{1}{2}}$-$watt^{-1}$ but require cooling to 80^oK. (See page 4.) HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The III-V and II-VI semiconductor detectors are available in photoconductive devices or photovoltaic devices. From 1-5 micrometers, binary compounds will suffice. Above 5 micrometers, the peak response as a function of wavelength can be varied in a II-VI ternary compound (for example, $Hg_x Cd_{1-x} Te$ and $Pb_x Sn_{1-x} Te$) by changing the ratios of the group II constituents.

A pyroelectric detector consists of a slab of pyroelectric material having two opposite face areas coated with conductive layers to form a capacitor. A change in temperature generates a signal current proportional to the pyroelectric coefficient. To optimize the signal, a material should possess a low heat capacity, low dielectric constant, and large pyroelectric coefficient. Since the signal current is proportional to the rate-of-change of the temperature, this detector is more attractive than other types of uncooled thermal detectors for higher frequency applications.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

These devices are used for remote sensing in earth resources missions, environmental pollution monitoring, and thermal mapping.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Infrared Detectors for Remote Sensing

7. TECHNOLOGY OPTIONS:

The detectivity of the II-VI ternary compounds can be increased to the point where it is practical to operate these devices at higher temperatures than 80 K. The detectivity of the pyroelectric can be increased to $\sim 10^{10}$ cm-Hg$^{\frac{1}{2}}$-watt^{-1}.

8. TECHNICAL PROBLEMS:

1. Control of homogeneity in III-V and II-VI materials restricts array construction.
2. Poor reproducibility of detector parameters in III-V and II-VI materials.
3. Relatively low operating temperature ($\sim 80^{\circ}$K) in the II-VI ternary materials.
4. Relatively low detectivity in pyroelectric detectors. (cont. on page 4)

9. POTENTIAL ALTERNATIVES:

If temperatures on the order of 35°K can be achieved for the desired mission, it is suggested that doped silicon detectors be employed because of their higher detectivity in the wavelength range greater than 5 micrometers. In addition, the detector preamplifier can be directly incorporated with the device.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP #506-18-21, "Electronic Devices and Components," contains elements bearing on this technology, such as an indium antimonide CCD sensor and pyroelectric detector materials investigations.

EXPECTED UNPERTURBED LEVEL 8

11. RELATED TECHNOLOGY REQUIREMENTS:

Advancement in preamplifier performance technology; improved material growth technology; small volume, low power cooling systems.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
PYROELECTRIC DETECTORS:																			
1. Elec. Component Des.																			
2. Component Development																			
3. Array or CCD Hybrid Fabrication																			
4. Space Checkout																			
III-V &II-VI COMPOUNDS DETECTORS:																			
1. Materials Growth																			
2. Detector Fabrication																			
3. Analysis																			
4. Ground Checkout																			
5. Space Checkout																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. "Infrared Technology for Remote Sensing," Special Issue, Proceedings of the IEEE, 63, No. 1 (1975).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** ______

1. **TECHNOLOGY REQUIREMENT (TITLE):** Infrared Detectors for Remote Sensing

4. CURRENT STATE OF ART: (cont'd.)

Over the wavelength range 1-20 micrometers, pyroelectric detectors have a relatively low detectivity ($D^* = 5 \times 10^8$ cm-Hz$^{1/2}$ -watt^{-1}) but require little or no cooling.

8. TECHNICAL PROBLEMS: (cont'd.)

5. Relatively long response times in pyroelectric detectors which restricts their practical operating frequency.
6. Pyroelectric detectors highly sensitive to vibrations.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Ultra-Narrow Band Filter for Remote Sensing PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Design and develop infrared bandpass filters of the Fabry Perot Interference type to advance the capability of IR spectroradiometers for the detection and measurement of line strengths in molecular spectra.

4. CURRENT STATE OF ART: Visible filters have been carried to level 6 (Fraunhofer Line Discriminator Program). IR filters are in the early design phase.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Ultra-narrow band filter requirements for atmospheric absorption experiments:

Wavelength range: 5 μ to 20 μ (2000 cm^{-1} to 500 cm^{-1})
Full width, half max. range: 3 X 10^{-4} μ to 1 X 10^{-3} μ (0.12 cm^{-1} tp. 0.024 cm^{-1})

Transmission: 0.50

Optical ray cone angle: 2^{o}

Operating temp: $80^{o}K$

By tilting the filter, limited wavelength tuning can be accomplished to scan several spectral lines in the IR spectrum.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. Filters to be incorporated into a differential absorption spectroradiometer to measure atmospheric gas composition and pollutants.

2. Global coverage of the Earth environment from air-Sat or Shuttle.

3. Provides greater spectral specificity and detection capability over present broadband filters used in LRIR or proposed LACATE sensors.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ______ PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

IR Laser tuning techniques may accomplish same measurements in differential absorption spectrometry.

8. TECHNICAL PROBLEMS:

IR Material selections, design for specific wavelength filters, wavelength shifts with filter temperature change, integration of filter and detector into compatible sensing subsystem.

9. POTENTIAL ALTERNATIVES:

Useful as a blocking filter in laser tuning differential absorption spectrometry.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Requires use with large diameter collecting optics (1 meter) and cooled detector filter subsystem.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ______________ PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses		—																	
2. Design		—	—																
3. Fabrication			—	—															
4. Ground Task				—	—														
5. Space Checkout					—	—													
APPLICATION																			
1. Design (Ph. C)						—	—												
2. Devl/Fab (Ph. D)							—	—											
3. Operations									—	—	—								
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE							Δ										
NUMBER OF LAUNCHES																	

14. REFERENCES:

Ultra-narrow band interference filter - AAFE Proposal Summer 1975

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Technology and Materials for Interference Filters and Anti-Reflection Coatings PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Remote Sensing of Stratospheric Gases

3. OBJECTIVE/ADVANCEMENT REQUIRED: More durable, stable, interference coatings for IR optical elements in the 1-20 μm spectral range. Must withstand prolonged operation at Cryogenic temperatures and/or in proximity with important trace constituents (HCl, SO_2, etc.)

4. CURRENT STATE OF ART: Multi-layer anti-reflection (MLAR) or filter coatings exist, but have not been space qualified for operation in gas filters or at suitable cryogenic temperatures for required life. HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Multi-layer AR and Filter Coatings have been used for several years in IR sensor systems. The system spectral response (particularly out-of-band) in operation has often not been that predicted based on the design and individual component measurements. The systems to-date have usually not been adequately evaluated after prolonged exposure to cryogenic temperatures or space and the long-term stability under such conditions. Nor have such coatings been used in proximity with gaseous constituents unless they were known to be inert. Present IR coating materials must be evaluated under realistic use conditions for stability over durations of six months to three years.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Multi-layer anti-reflectance coatings are needed in all electro-optical sensors.

Background blocking filters are required in all narrow-band electro-optical sensors.

Trace constituent measurements will require maximum sensitivity achievable and therefore require coatings used at cryogenic temperatures (30K to 150K).

Trace constituent measurements will require maximum spectral discrimination thus requiring coating of elements in proximity with "active" gases.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Improved Technology and Materials for Interference Filters and Anti-Reflection Coatings

7. TECHNOLOGY OPTIONS:

Operate at less than optimum sensitivity without blocking filters to reduce background.

Operate at less than optimum sensitivity without MLAR to increase throughput.

8. TECHNICAL PROBLEMS:

Expected chemical/thermal reactions which destroy or change characteristics of "tuned" coatings in use. Development of new coating materials/techniques to improve performance. Spectral performance in "fast" (F/1) optical systems.

9. POTENTIAL ALTERNATIVES:

Operate at less than optimum sensitivity without blocking filters to reduce background.

Operate at less than optimum sensitivity without MLAR to increase throughtput.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Limited experiments with available coatings to be performed under low priority/funding SRT activities for short term use and limited consituents.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Technology and Materials for Interference Filters and Anti-Reflection Coatings — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Materials Evaluation	x	x																	
2. New Materials Development	x	x	x																
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)				x	x														
2. Devl/Fab (Ph. D)						x	x												
3. Operations								x											
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE					x												
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

B-2 GLOBAL AEROSOLS AND GASES EXPERIMENT

Application

The study and analysis of the effect of particulates in the atmosphere has led to serious consideration of their long range effects on the global radiation heat budget and the corresponding impact on global circulation and climate. The particulates are of natural origin (such as dust storms, forest fires, volcanic eruptions, water droplets, micro-meteorites) or are man-made pollutants (such as produced by automobile exhausts, industrial smoke, waste burning, etc.). These particulates, which are injected into the atmosphere by upwelling air currents, volcanic eruptions, and normal atmospheric chemistry (gas-to-particle generation) or by the micro-meteorites trapped in the atmosphere, have a marked effect on the amount of radiation not only reaching the ground, but the amount of heating in the atmosphere caused by their absorption of radiation. As man makes more and more of an impact on his environment due to the rapidly developing technology, it becomes increasingly imperative to study the background level of these particles to monitor how man is changing or affecting the balance in the atmosphere, and what effects these aerosols will have on such things as climate, solar radiation dosage, man's health, food production, etc.

Payload Description

The measurement of aerosols should include their physical and chemical characteristics and their spatial (particularly vertical) distribution. Consideration should also be given to transport mechanisms on a global basis. The measurement must be approached with various experimental and analytical techniques in order to obtain a more complete picture of what is occuring in the atmosphere. Several techniques are proposed as a Shuttle payload. All techniques are passive, but would be complemented by the active laser systems discussed elsewhere within this report.

The passive probing systems considered here are based on the measurement of attenuation of direct solar radiation (the "attenuation" system), of the angular distribution of the intensity (the limb-scattering system) or the polarization (the polarimetry system) of solar radiation scattered by the atmosphere.

Camera photography and photoelectric detectors are the prescribed recording devices in this connection.

The rationale for considering these systems for a Shuttle payload is described below.

1. ATTENUATION SYSTEM

Payload Description

A system is desired which will monitor the extinction of sunlight as a function of solar elevation to measure the aerosol burden in the atmosphere. This system would operate in the attenuation mode at spacecraft sunrise and sunset to obtain vertical profiles of stratospheric aerosols and by use of multi-wavelength coverage (5 to 6 channels in the 9.38 μm to 2.0 μm range) obtain information to characterize their size distribution. The use of infrared detectors in a photometer of this type could also be made to sense gaseous constituents in the upper atmosphere over the long path integration afforded by occultation. Measurements of H_2O, CH_4, O_3 and others in absorption could then be made. Studies would then proceed related to gas-to-particle conversion in the atmosphere involving gases such as HNO_3, H_2SO_4 and O_3. The need for development of pyroelectric detectors and pin silicon photodiode detectors whose response is unaffected by temperature changes is manifest. This measurement technique is limited in its coverage because of the sunrise-sunset mode of operation, however.

Required Technology

The development and construction of the pin silicon photodiodes that can operate at 1.0 μm without large sensitivity changes with temperature is required. Presently, the silicon photodiode responsivity is very temperature sensitive at 1 μm - about 0.5% per 0^{o}C. This change would appear, for example, as a single change with solar heating. One solution is to extend the peak spectral sensitivity toward 1 μm. This, however, may force a more undesirable mode, i.e., reverse bias. These diodes are needed in remote sensing of aerosols since 1 μ m is an atmospheric "window" region with no interfering gaseous absorption.

The technology schedule for analysis and design is 7/75 to 7/76 and for breadboard and test 1/76 to 3/77. The payload should be ready by 1980.

2. POLARIMETRY SYSTEM

Payload Description

A third system is desired which will provide information on the spatial and physical characteristics of aerosols by measuring the spectral and polarization characteristics of upwelling radiation from the atmosphere in the visible and near infrared wavelength regions. The degree of polarization increases with increasing scattering angle, being nil at zero degrees, from the sun. The instrument proposed for development should have no moving parts for mechanical simplicity and greater accuracy. Analysis of polarization information of upwelling radiation will permit modeling of the tropospheric aerosols, thereby permitting inputs to the global circulation of the polarimeter which is extremely valuable and could be incorporated into the instrument, would be to scan the aureole (the region from the sun's limb to about 20^{o}) with the polarimeter. One of the parameters of the aerosols that the polarization measurement technique has shown potential for measuring with greater sensitivity is the imaginary part of the refractive index of aerosols. An analysis of the polarization variation in the forward scattering of the aureole would allow characterization of aerosols in the stratosphere that would complement the upwelling measurement made over the same area by the polarimeter. A field of view change, instrument gimbaling, and a neutral density filter to reduce the intensity of the direct solar radiation, would be required for this measurement to be accommodated. This system would also permit attenuation measurements as described in Section 2. (Attenuation System)

One of the advantages of the polarimeter system is that it can continuously monitor the atmosphere unlike in the attenuation system, where the sunset/sunrise positions are a necessity.

Required Technology

The development of a no moving part space qualified polarimeter that can operate through narrow spectral bands within the spectral region from approximately 0.35 μm to 1.0μ m needs to be developed.

A Faraday technique has been breadboarded within industry and looks promising. The wavelength sensitivity throughout the visible is a technical problem to be considered.

The inversion of the polarization data to obtain the aerosol characteristics still needs more effort. This theoretical aspect of the problem should be given as much weight, if not more, as the technological aspect.

The technology schedule is as follows: Test breadboard (1/76 to 1/77), lab and field measurements (6/76 to 6/77), redesign and fabrication (1/77 to 6/78). The theoretical simulation and inversion aspects of the measurement can be completed within 1½ years (by 1/77).

3. LIMB SCATTERING SYSTEM

Payload Description

Another valuable technique that can be used from the Shuttle is that of limb scattering measurements using a multi-channel photometer. These measurements would allow determination of stratospheric aerosol characteristics and certain gases (O_3, O_2 and molecular oxygen) by looking at scattered solar radiation from the earth's limb. The coverage afforded by such a measurement is extended considerably but the analytical process for data inversion is not quite in hand presently. Much work still needs to be done on the theoretical side. Efforts are underway to bring the analysis to be better understood. A photometer covering 5 to 6 channels in the visible and near infrared which could scan the earth's limb in various azimuth angles would be required for this measurement.

One of the major advantages of such an instrument is that it lends itself to continuous monitoring of the earth's atmosphere since the sunset/sunrise positions are not needed as is the requirement with the attenuation techniques. Thus, an important aspect of this system is its possible application for systematic spatial and temporal determinations of the aerosol properties on a global scale. The dynamic and temporal variations of the aerosol properties have not been monitored previously on a global basis. It should yield information about the important dynamic quantities, such as local residence time, creation, and destruction processes, ozone density changes and high altitude clouds.

Required Technology

The technology requirement is the development and the construction of a scanning multi-wavelength photometer, which is space qualified.

At the same time, work on an increased pace on the theoretical inversion algorithms needed to extract useful information from the intensity data should be given high priority. The solution of this difficult problem, often referred to as the inverse multiple scattering problem, is attracting in recent years considerable attention among world atmospheric scientists.

4. PHOTOGRAPHIC SYSTEM AND SUN SHAPE EXPERIMENT

Payload Description

A photographic film is one of the most compact devices for storing information, and highly sophisticated small format (70mm or 35mm) photographic equipment, excellent for scientific, with the added convenience of portability, are now the state of the art items. Not only does camera photography record a visual scene, but it records the full field of view simultaneously: an advantage no scanning photoelectric device can provide.

The multi-angle, narrow wavelength-bandwidth photography can be carried out in the sunset/sunrise mode or the limb scattering measurement mode or the polarization measurement mode. In the sunset/sunrise mode, the measurement of the direct solar radiation and the scattering intensity and polarization of the radiation by the atmosphere within the aureole surrounding the sun's disk can be simultaneously carried out. Thus, the relatively inexpensive photography cannot only measure the extinction, scattered intensity and polarization of solar radiation by aerosols (and gases), from which aerosol characteristics can be determined, but also measure the shape of the sun's disk, from which information about the altitude variation of the atmospheric refractive index can be obtained. Limb pictures before sunrise or after sunset will also be valuable in these analyses.

Required Technology

The required technology is the development of a lightweight portable, external occultation neutral density filter mechanism, which will permit photography of the sun and its aureole through narrow spectral bands (and polarizers when used), and at the same time remove or reduce the problems of flare and stray light to an insignificant level.

There is also a need to develop or improve techniques in which the 6-order dynamic range EG&G film or the AGFA contour films can be used.

The basic technology requirements can be completed by 12/77 ($2\frac{1}{2}$ years).

The synergism afforded by conducting several of these experiments in consonance can be seen from the fact that several are sensitive to the total burden of aerosols in the atmosphere while others are sensitive to upper atmospheric inputs primarily. Other effects such as comparison of measurements by different modes over the same geographical region or by the same basic measurement by several different techniques also act to reinforce one another.

The broadband gaseous measurement alluded to in (1) can act as a complementary and supplementary measurement to a limb scanning instrument (narrow-band infrared) for substantiating the quantitive inference of trace constituents in the upper atmosphere.

Measurements of limb scattering and occultation can be compared for agreement since both will produce vertical distribution of aerosols in the upper atmosphere.

Tropospheric measurements by lidar and polarimetry can be compared for the proper interpretation and calibration of data.

Associated Mission Model

The proposed Shuttle payload supports the Outlook for Space themes: Prediction and Protection of the Environment and the Protection of Life and Property, and especially the objectives dealing with climate (OFS-023), Tropospheric Pollutants (OFS-032), Large Scale Weather (OFS-021), Stratospheric Changes and Effects (OFS-024).

The payload supports the following 1973 mission model payloads:

1. EO-3, The Earth Observatory Satellite (18 launches, 1978-91)

2. EO-4, The Synchronous Earth Observation Satellite (8 launches, 1981-91)

3. EO-5, Special Purpose Satellite (18 launches, 1977-91)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): No Moving Part Pclarimeter PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop a space qualified no moving part polarimeter to measure the spectral and polarization characteristics of upwelling radiation.

4. CURRENT STATE OF ART: Moving part systems have been developed for helicopter and aircraft use.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The system must be capable of measuring from a spacecraft the spectral and polarization characteristics of upwelling radiation with no moving parts. A Faraday technique has been breadboarded by TRW and looks promising. No system is available presently. The spectral interval would be from approximately 0.35 to 1.0 μm.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

This system would be used to characterize tropospheric aerosols.

This technology advancement should be carried to an experimental demonstration on an early Shuttle flight. Simulation of the measurement would be impossible from other platforms.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): NMP Polarimeter PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Moving part polarimeters could be developed for space applications, but the no moving part system would be much more attractive.

8. TECHNICAL PROBLEMS:

λ sensitivity throughout visible.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

AAFE supported early development of moving part system.

RTOP # 160-44-71 supported helicopter measurement program.

No FY 76 funding is available.

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO.

1. TECHNOLOGY REQUIREMENT (TITLE): NMP Polarimeter

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Test TRW Breadboard																			
2. Lab & Field Meas.																			
3. Redesign																			
4. Fabrication																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. "Development of An Experiment for Visible Radiation Polarization Measurements from a Satellite," by Z. Sekera and R. E. Bradbury, NASA Contractor Report, NASA CR-2297, November 1973.

2. "Measurement and Analysis Program Using Visible Radiation Polarization Data Obtained from a Helicopter Borne Polarimeter," by K. R. Jenkin et al., TRW, under contract NAS1-12298, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Red Extended Pin Silicon Photodiodes

PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop pin silicon photodiodes that can operate at 1.0 μm without large sensitivity changes with temperature.

4. CURRENT STATE OF ART: Presently silicon photodiode responsivity is very temperature sensitive at 1 μm.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Silicon photodiodes temperature sensitivity at 1 μm is large - 0.5% per ^{o}C. This change would appear, for example, as a signal change with solar heating. One solution is to extend the peak spectral sensitivity toward 1 μm. This, however, may force a more undesirable mode, i.e., reverse plan.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) These diodes are needed in remote sensing of aerosols since 1 μm is an atmospheric "window" region with no interfering gaseous absorption.

(b) Could be used on SAM II/Nimbus-G, SAGE/AEM B, and future Shuttle missions.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Silicon Photodiode... PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

(a) Germanium might be applicable.

(b) Active temperature control.

8. TECHNICAL PROBLEMS:

Construction of such diodes.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP # 642-12-13 is developing the SAM II/Nimbus-G hardware.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Silicon Photodiode... PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis & Design																			
2. Breadboard & Test																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

B-3 LASER REMOTE SENSING OF THE ATMOSPHERE

Application

The application of laser remote sensing is to the detection of constituents and pollutants in the earth's atmosphere from 80 kilometers to the ground and to the effects that result from their proliferation. One of the effects concerns potential changes in climate, whereby changes of only 1°C may have far ranging economic influence due to changes in crop production, etc. Another effect concerns the photo-chemical reduction in stratospheric ozone causing increased UV radiation from space with possible danger to life and material. The effects of gaseous pollutant and aerosol increase near the ground may also have serious effects on life and material.

Payload Description

The sensor systems consist of (1) A passive IR tunable laser heterodyne spectrometer in the 3 μm to 12 μm range for measuring vertical distribution of pollutants/constituents in the upper troposphere and stratosphere using solar radiation, up-welling thermal radiation of the earth and the atmosphere and radiation emitted by the earth's limb. (2) An active IR tunable laser differential absorption spectrometer system in which the radiation from a tunable high pressure/high energy gas laser is transmitted vertically downward to the earth's surface, and is reflected upward by the earth's surface to the heterodyne receiver on the Shuttle. The distribution of pollutants in the troposphere to the ground, can be determined from variation of zones. (3) Differential absorption LIDAR for measuring the vertical distribution of gaseous constituents and pollutants through laser ranging, using backscattering from aerosol and molecules. This system has the potential of simplicity. Since optimization of scattering requires operation in the UV, visible and near IR, the technique is restricted to pollutants with sufficiently strong absorption lines in this spectral range; it also depends on further development of lasers with sufficient power and efficiency in the UV, visible and near IR. Thus, this sensor system may be applicable to more advanced payloads than (1) and (2). The lasers developed for this technique also are needed in other payloads for sensing aerosols, cloud heights and thickness sensor system. (4) A passive IR tunable laser heterodyne spectrometer in the 15 μm range for improved measurement of atmospheric temperature profiles through measurement of CO_2 profiles (CO_2 has a constant mixing ratio). (This input was made by L. Korb from GSFC).

Systems (1) and (2) will be used to measure O_3, H_2O, CO_2, NH_3, CH_4, NO, NO_2, Freons, and ClO. Extensive computer modelling of these remote sensing techniques have been performed to corroborate their feasibility from the Shuttle. The advantages of the technique are high specificity in the presence of interferent gases, high detection sensitivity, fast observation times, and in the active laser mode, (2), the important capability of sensing near the ground Technology readiness for (1) and (2) can be demonstrated from the Shuttle for key pollutants in FY81. The remaining pollutants will be investigated through FY83. For sensor system (3) the required laser development in the UV, visible and near IR should delay a Shuttle demonstration to the period after FY85.

Technology Requirements

The high specificity and sensitivity of heterodyning is obtained by beating the radiation from passive (natural) or active (laser) sources with that from a tunable laser local oscillator on a square law detector thereby transforming the spectral information from the infrared to the microwave range, where small spectral bandwidth and removal of noise sources if obtained. The technology requirements for receiver in systems (1), (2), and (4) concern improvements in operation of solid state tunable diode lasers used as local oscillators. For pollution measurements, the IR range from 3 to 12 um is of major interest and for temperature measurements, the CO_2 band in the 15 um range Diode lasers have the required tuning range, but further development is needed for stable single mode operation at powers 1mW on a routine basis. Recently, Diode lasers have been operated at liquid nitrogen temperatures (in contrast to previous liquid helium operation), but this operation needs to be established on a routine basis. The advantage is considerable power reduction for the closed cycle cooler, making the Diode laser potentially useful for satellite--as well as Shuttle operation.

The technology requirements for sensor system (2) concern further development of tunable high pressure/high energy gas lasers with tuning across pressure broadened laser lines. The deficiency of these lasers and the powers required are compatible with certain Shuttle missions (and potentially for satellite missions). Stability and spectral resolution of tuning needs to be further improved and techniques for simultaneous operation on several laser lines requires more investigation. Operation on several laser lines is necessary for the differential absorption technique where laser lines "on" and "off" atmospheric absorption lines are needed; simultaneous operation of pulses on different laser lines insures the same footprint of the reflected laser radiation on the ground, thus avoiding statistical problems in return signal interpretations. Frequency conversion techniques need to be further developed to extend the tuning range of gas lasers (CO_2, CO, DF, HCl, HF).

The technology requirement for sensor system (3) concerns development of high energy lasers with high efficiency in the UV, visible and near IR. In the near IR, for isolated cases, some of the gas lasers in sensor system (2) may be directly used (e. g. HCl or DF lasers for remote sensing of HCl), but in general, improved conversion techniques into the near IR are needed. For the UV, the development of efficient frequency doubled tunable dye lasers is required. The conversion efficiency from optical pumps, lasers, or flashlamps, to dye laser radiation is comparatively high, but the efficiency of these optical pumps needs to be increased and other optical pumping sources developed.

The development of efficient Nd: YAG lasers which are space qualified is necessary for aerosol and cloud studies.

Associated Mission Model

This payload is intended to be used on the Shuttle ATL payload which is scheduled to be launched in 1981.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Tunable Laser Heterodyne Spectrometer (TLHS)

PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Sensing, Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop tunable lasers for use as local oscillator in a TLHS for remote sensing of vertical distribution of constituent and pollutant gases with higher specificity and sensitivity than available with other sensors.

4. CURRENT STATE OF ART: The TLHS, as other passive devices, utilizes natural radiation sources for remote sensing of the atmosphere such as solar radiation absorbed by the atmosphere (See p. 4). HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Tunable diode lasers can be tailored to emit in the desired wavelength region by adjusting the chemical composition of ternary semi-conductor compounds. Most of the tunable diode laser studies[3,4] are performed with the lead chalcogenides $Pb_{1-x}Sn_x$ (6.5 to 34 μm), $PbS_{1-x}Se$ (4 to 8.5 μm), and the recently used $Pb_{1-x}Gd_xS$ (2.5 to 4 μm). The diode laser can be tuned by varying the diode temperature (generally through the current), varying an applied magnetic field or external pressure. The high pressure gas laser and the optical parametric oscillator technologies are described in technology requirement on lasers for remote sensing.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The TLHS is important for passive and active (laser) remote sensing techniques. Heterodyne remote sensing has the following advantages over other passive remote sensing techniques. (1) Higher specificity - based on its high spectral resolution the TLHS provides better discrimination against generally present interferent gases. Thus pollutants can be detected with greater accuracy. (2) Higher sensitivity - the TLHS removes most of the noise sources (detector/background) common to direct infrared detectors and permits the ultimate in detection (quantum noise limited operation).

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** ______________

Tunable Laser Heterodyne Spectrometer (TLHS)

7. TECHNOLOGY OPTIONS:

Concerns techniques for "active" laser remote sensing discussed under a separate technology requirement. Actually, the passive TLHS and the active tunable laser techniques complement each other.

8. TECHNICAL PROBLEMS:

(1) Single mode operation of tunable laser local oscillators over a wide tuning range at powers > 1 mW. The diode laser has the proper tuning range but needs to achieve > 1 mW single mode on a routine basis. Diode laser operation at 77^{O}K needs to be further developed for operation with a low power ($\sim$ 100 W) cooler. High pressure lasers: CW waveguide lasers have sufficient power but their pressures and tuning range need to be increased. High pressure pulsed lasers have the potential of extending their tuning range over the (See p. 4)

9. POTENTIAL ALTERNATIVES:

The potential alternatives are other passive remote sensing techniques and laser remote sensing.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

SR&T developments of the TLHS and tunable diode laser local oscillators are performed under RTOP 506-18-12. The development of other laser types which have potential as local oscillators is discussed under the technology requirements for tunable lasers for remote sensing. Application of a select frequency gas laser heterodyne spectrometer is performed under a joint AIL (Airborne Instrument Lab)-LRC AAFE program (RTOP 638-10-00).

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Improvement of sensitivity and bandwidth of square law detector and associated electronics. Development of high efficiency closed cycle coolers.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Tunable Laser Heterodyne Spectrometer (TLHS) — PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. Tunable Diode L (1 mW, 77^{o}K)																			
1a. Advanced Systems																			
2. TLHS Component Design																			
3. Breadboard Test																			
4. Fabrication																			
5. Final Tests																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Operations with advanced Tunable lasers for TLHS																			

13. USAGE SCHEDULE:

																TOTAL
TECHNOLOGY NEED DATE																
NUMBER OF LAUNCHES																

14. REFERENCES:

1. R. K. Seals: Analysis of Tunable Laser Heterodyne Radiometry: Remote Sensing of Atmospheric Gases. AIAA J., vol. 12, no. 8, Aug. 1974.
2. R. T. Menzies: Laser Heterodyne Detection Techniques. Chapter 6 of Laser Monitoring of the Atmosphere, E. D. Hinkley, Ed. (Springer).
3. F. Allario, R. K. Seals, P. Brockman, R. V. Hess: Tunable Semiconductor Lasers and Their Application to Environmental Sensing. 10th Anniversary Mtg. of the Society for Engineering Science. November 1973.
4. E. D. Hinkley, K. W. Nill, and F. A. Blum: Infrared Spectroscopy with Tunable Lasers. Laser Spectroscopy of Atoms and Molecules. Book chapter in "Current Topics in Physics," Springer. To be published.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE):

Tunable Laser Heterodyne Spectrometer (TLHS)

4. CURRENT STATE OF ART (cont'd.)

upwelling thermal radiance of the earth and the atmosphere and radiation emitted by the earth's limb.[1,2] The TLHS obtains high specificity and sensitivity by beating the radiation from passive (natural) or active (laser) source with that from a tunable laser local oscillator on a square law detector, thereby transforming the spectral information from the infrared to the difference frequency in the microwave range which permits tuning across atmospheric spectral lines with small spectral bandwidth and removal of noise sources except quantum noise. The requirements for operation of a tunable laser as local oscillator are single mode power in excess of 1 mW and sufficient tuning range to cover all important constituents and pollutants. (1) Tunable infrared diode lasers[1,2] have the required tuning range and have been operated multimode at considerably higher powers. Transverse single mode operation has been obtained but single longitudinal mode > 1 mW is still not being attained on a routine basis. In the past infrared diode lasers operated only at liquid helium temperatures but recently[3] CW operation has been achieved at liquid nitrogen temperatures by using liquid phase epitaxy growth techniques to fabricate double heterostructure devices. This temperature increase is very important since it permits reduction in power of closed cycle coolers (from $\sim$ 1 kW to $\sim$ 100 W) which are desirable for stable temperature operation. (2) High pressure gas lasers (see also technology requirement on laser remote sensing) are tuned across pressure broadened lines ($\sim$ 3 GHz/atm); CW waveguide lasers operate presently at pressure < 1/2 atm and high pressure pulsed lasers (presently under development) can operate up to pressures > 10 atm with corresponding tunability over a wide region. Select frequency gas lasers (at lower pressures) are being used as local oscillators for a limited number of gases. Parametric oscillators (pumped by Nd:YAG lasers)have so far not been operated at high spectral resolution over the entire IR range.

8. TECHNICAL PROBLEMS: (cont'd.)

entire IR (including frequency conversion techniques) but their tuning stability needs to be improved (e.g., through techniques discussed under the technology requirement for laser remote sensing). The Nd:YAG laser pumped optical parametric oscillator (OPO) has sufficient power but has not been routinely tuned over the entire IR with sufficiently high spectral resolution. The short pulses limit the bandwidth of the radiation. (2) The TLHS techniques, as other passive techniques, depend on radiation or absorption "on" and "off" atmospheric absorption lines. Thus it is desirable to extend the TLHS technique to multiline operation. No major difficulties are expected, which would give the TLHS technique another advantage over other IR, visible, and UV detectors where such simultaneous line operation may be more difficult.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment

2. TECHNOLOGY CATEGORY: Sensing, Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop tunable lasers from IR through UV, to measure constituent and pollutant gases, aerosol and clouds at powers compatible with shuttle requirements.

4. CURRENT STATE OF ART: Depends on the lasers used in the various sensing techniques. Gases: (1) Differential Absorption with Reflection Sensing (DARS)[1,2,3] from earth, clouds. (See pp. 4,5)

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Tunable High Pressure/Energy IR Lasers: Continuous tuning occurs across the pressure broadened laser lines, e.g., for CO_2 lasers the tuning rate is 3 GHz/atm. Overlapping of CO_2 laser lines occurs > 10 atm so that continuous tuning from ∿ 9 to 11 μm becomes possible, many pollutants and constituents do not require such a wide continuous tuning range. High pressure CO (∿ 5 μm), DF (∿ 3.8 μm), and HF (∿ 2.7 μm) lasers need to be further developed. Efficient 15% frequency doubling with CdGeAs crystals has been obtained and an efficiency > 30% is projected. Frequency mixing of several laser wavelengths and optical pumping of new lasing molecules for extending the wavelength range from 1 to 11 μm are promising. In contrast to waveguide lasers, which operate with a wall controlled discharge at low pressures (< 1/2 atm) and tuning range and powers of the order of a few watts, for the tunable high pressure/engergy laser uniform discharges are obtained by various pre-ionization techniques in a larger volume improving uniformity of laser output and laser efficiency. The several laser wavelengths needed in the differential absorption (see p. 5)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

In the past remote sensing techniques of the atmosphere over long ranges from satellites were primarily of the passive type and laser techniques have been used for shorter ranges. The development of more efficient lasers and of improved remote sensing techniques, together with future availability of the shuttle make such long range laser remote sensing techniques attractive.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** PAGE 2 OF 7

Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment

7. **TECHNOLOGY OPTIONS:**

Concerns a novel passive technique using a tunable laser as local oscillator in a so-called laser heterodyne spectrometer, which increases the sensitivity and spectral resolution of passive radiometers. The laser heterodyne spectrometer (discussed under a separate Definition of Technology Requirement) is not just a technology option, it actually complements the present active laser techniques. Laser remote sensing techniques have certain advantages and disadvantages. The advantages of laser techniques are (1) differential absorption techniques (DIAR, DIAL) are superior for measuring gases close to ground level, (2) they have less dependence on atmospheric temperature distribution in contrast to passive techniques which depend on radiances, (3) they appear to be better suited for measuring gases below concentration bulges, e.g., in O_3 which may also contain NO_x bulges from stratospheric flight, (4) by providing an independent pulsed light source they permit day and night (see p. 6)

8. **TECHNICAL PROBLEMS:**

Long range remote sensing techniques from the shuttle and especially from satellites require highest possible efficiencies for lasers and frequency conversion, and frequency stable operation simultaneously on several narrow laser lines. Reasonable extrapolation of present gas laser efficiencies indicates that use of these lasers by themselves or as pumping sources of crystals or other gases offer the possibility of performing shuttle experiments in the IR range from 11 to 1 μm, compatible with shuttle powers (see p. 6)

9. **POTENTIAL ALTERNATIVES:**

The potential alternatives are passive remote sensing techniques and various in-situ measurements.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

SR&T development and feasibility studies of tunable high pressure gas lasers for shuttle remote sensing are performed under RTOP 506-18-12; applications of these tunable, high energy density lasers to laser energy transmission and energy conversion is performed under RTOP's 506-25-55 and 506-21-42. Feasibility studies for a variety of tunable lasers for shuttle remote sensing are performed under (see p. 6)

EXPECTED UNPERTURBED LEVEL __

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Small, lightweight power supplies. Optimization of heterodyne receiver.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. Tunable High Pressure IR L																			
1.a. Frequency Conv.																			
2. Advanced (Vis., UV)L																			
3. Component design IR L																			
4. Breadboard Tests																			
5. Final Tests																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Oper. with frequency Conv., Advanced L																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. R. K. Seals and C. H. Bair: Analysis of Laser Differential Absorption Remote Sensing Using Diffuse Reflection from the Earth. Second Joint Conference on Sensing of Environmental Pollutants. Dec. 10-12, 1973.

2. R. V. Hess and R. K. Seals: Applications of Tunable High Energy/Pressure Pulsed Lasers to Atmospheric Transmission and Remote Sensing. NASA Technical Memorandum. TMX-2010.

3. Computer Feasibility Studies for Remote Sensing of Gases from Shuttle with DARS and DIAL (Visible and UV) performed by R. T. Thompson (ODU) and E. E. Remsberg, NASA LaRC. To be published.

4. M.L. Wright, F. K. Proktor, L. S. Gusiorek, E. M. Liston: A Preliminary Study of Air Pollution Measurement by Active Remote Sensing Techniques. Stanford Research Institute Final Report, prepared for NASA LRC Contract NAS1-11657. To be published.

(See page 7)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. **TECHNOLOGY REQUIREMENT (TITLE):** Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment **PAGE** 4 **OF** 7

4. CURRENT STATE OF ART: (cont)
(2) Differential Absorption Lidar (DIAL) with ranging by atmospheric scattering, 3,4,5.
(3) Fluorescence Lidar measurements for Shuttle Environment. 6 Aerosol Clouds: Lidar measurements of atmospheric aerosol distribution, cloud height and thickness.
Gases: (1) DARS is used to measure column content with laser wavelengths "on" and "off" absorption lines, and vertical altitude profiles with several wavelengths on absorption lines to include the variation of pressure broadening with altitude. For column content measurements from the Shuttle pulse energies <1 Joule 1, 2, 3 and average powers <10 W (assuming a repetition rate of 10 p.p.s.) should be sufficient for O_3, CO, N_2O, H_2O in the IR, H_2O in the visible, and O_3 in the UV. These results are obtained by optimizing detectors (e.g., heterodyning in the IR, yielding several orders of magnitude improvement), "on" and "off" wavelengths, and telescope size. All optimization have not yet been performed in ref. 4. Higher pulse energies and average powers are needed for less abundant gases SO_2, HCl, NO, and Freons (except for industrial corridors and Shuttle or aircraft exhausts). The choice of wavelength range crucially depends on the availability of efficient lasers to meet the Shuttle power limitations, or mission constraints for auxiliary power (aircraft power limitations are less severe). In the IR, tunable high pressure/energy CO_2 lasers and some other lasers at shorter wavelengths (CO, DF, HF) are capable of efficiencies $>10\%$ and with frequency conversion have efficiencies into the entire IR range $>3\%$. Thus, the required average power on the Shuttle would vary from <100W (for 10 p.p.s.) to somewhat higher powers for the more sophisticated experiments In the visible, tunable dye lasers attain presently an efficiency of $\sim0.3\%$ and with frequency doubling into the UV $\sim0.1\%$, thus for 10W avg. laser power at least 3 kW Shuttle power for H_2O (visible) and 10 kW for O_3 (UV) would be needed Vertical altitude profiles, which depend on pressure broadening with altitude require IR operation; the power requirement is somewhat higher than for the column content. (2) DIAL obtains vertical altitude profiles through ranging by scattering from aerosols and molecules and thus improves with decreasing wavelength. The pulse energy requirements in the visible and UV vary from several Joules (H_2O, O_3) to >10 Joules (e.g., SO_2) with correspondingly large Shuttle power requirements due to low/laser efficiencies. Atmospheric constituents and pollutants have fundamental and overtone absorption lines in the near IR (1 to 5 µm) where scattering becomes sufficient for DIAL applications. Tunable optical parametric oscillators using frequency conversion of solid state lasers in the near IR presently do not have sufficient energies and efficiencies for Shuttle use (but may be useful for ground or aircraft use). Coincidences of gas lasers with molecular absorption lines (e.g., DF laser with HCl from Shuttle exhaust have been studied for DIAL measurements in the near IR (~3.8 µm). A combination of gas lasers studied for DIAL measurements in the near IR may show promise for Shuttle applications. (3) Fluorescence Lidar has the potential of measuring gases such as O(1304.87 Å), H(1216 Å), Ar(1066.66 Å, N_2 (1300 Å) in the immediate Shuttle environment 6 (0.1 to 10 km) and Na(5590 Å) at a longer range (115 km). At present the efficiency of producing far UV frequencies through frequency multiplication of laser radiation is very low and only few select frequency lasers exist in this region.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment

4. CURRENT STATE OF ART: (cont)

The recent development of high pressure excimer lasers may be useful for this application; measurement of Na in the visible range should provide no difficulties. Aerosols, Clouds: As discussed in the Shuttle payload proposal on Remote Sensing of Aerosols by L. Kopia and P. McCormick, the backscattered radiation from a Lidar system can be used to obtain much needed information for a variety of problems, such as cloud height thickness, and type (phase state of cloud), vertical profiles of stratospheric and mesopheric aerosols and the tropospheric aerosol maximum mixing height. Theoretical feasibility studies 7, 4, 8 indicate that aerosol distribution/measurements in the stratosphere down to the mixing height, with range resolution of ∿ 1 km could be performed at ruby laser wavelength (0.693 μ m) at pulse energies of the order of 1 Joule and at Nd:YAG laser wavelength (1.06 μ m) with pulse energies of the order of 10 Joules, could be performed at night time. Measurements of the top heights of several cloud types could be performed with similar energies during daylight, but measurement of cloud thickness would require higher energies or similar energies at night time. A two color system (Kopia and McCormick) using 0.6943 μm or 1.06 μ m and their second harmonics would allow, in principle, complete separation of the molecular and aerosol components of the backscattered radiation for a unique aerosol measurement. The key problem is development of efficient lasers and detectors. The present efficiency of Nd:YAG lasers is at best ∿ 1% and of ruby lasers a fraction of a %. Thus, for both lasers, the power requirements for rep. rates of 1 pps would vary from several hundred watts to 1 kW. The need for efficient lasers in the visible and UV for aerosol and cloud measurements is similar to that for indifferential absorption measurements of atmospheric constituents and pollutants.

5. DESCRIPTION OF TECHNOLOGY: (cont)

technique must operate close to simultaneously to avoid detrimental effects due to change in scattering from the ground (diffuse reflection) or from the atmosphere and turbulence produced by wavelengths at different times. This may be obtained through use of ring lasers and unstable cavities, which also provide greater stability for fine tuning at the required narrow spectral output. Tunable Dye Lasers and other Visible and UV Lasers: The efficiency of tunable dye lasers is presently very low, ∿0.3% in the visible and corresponding lower, ∿ 0.1% for frequency doubling in the UV. The dye lasers are optically pumped by flashlamps or other lasers. The efficiency of conversion from these pumping sources is high, up to 40%. Thus, the key problem is the inefficiency of visible and UV lasers and flashlamps. The efficiency of visible ruby lasers is a fraction of a %. The efficiency of Nd:YAG (1.06 μ m) lasers is 1% and somewhat higher efficiencies have been reported with the hope of approaching visible (doubled) laser efficiencies of 1%. Visible copper chloride lasers (.5100 and .5182 μ m) have recently been operated by A. Russel and N. Nerheim at JPL at efficiencies of 1%. Nitrogen lasers (.3371 μ m) have efficiencies of < 1%. Excimer lasers have shown high efficiencies in the UV and have potential for the visible. Tunable Optical Parametric Oscillator (OPO) and Radar-IR Lasers: An Nd:YAG laser (1.06 μ m) is generally used as laser source with frequency conversion in an $LiNbO_3$ crystal. The conversion efficiency is high > 30%, but the laser efficiency is not, ∿ 1%, thus the combined efficiency is ∿ 0.3%. A potential (cont)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment PAGE 6 OF 7

5. DESCRIPTION OF TECHNOLOGY: (cont)

improvement concerns use of the more efficient gas lasers with the OPO or with frequency mixing of different laser frequencies with the goal of achieving an order of magnitude higher efficiency of $\sim$3% in the near IR. For IR operation considerably increased signal/noise is obtained through use of a heterodyne receiver (discussed under separate technology requirement).

7. TECHNOLOGY OPTIONS (cont)

operations and comparative reduction in background noise. The potential disadvantage of laser techniques is higher power requirement. The comparatively low powers required for certain efficient laser techniques, however, makes them attractive.

8. TECHNICAL PROBLEMS: (cont)

<100 W to several kW. Use of an Nd:YAG laser as pumping source for frequency converters (optical parametric oscillator) in the near IR would require improvement in efficiency with a narrow spectral band output. Tunable diode lasers have a wide tuning range but not sufficient power. Operation of tunable dye lasers in the UV would be of great interest for DIAL experiments, but their present efficiency is too low. Increases in efficiency of dye laser pumping sources, e.g., Nd:YAG with frequency doubling, nitrogen-, argon-, copper chloride vapor-, and excimer lasers are required or the possible use of high pressure dye vapor lasers with electric discharge excitation. Another alternative is efficiency increase of flashlamps with new pumping techniques and improved matching of the dye spectrum. For example, laser produced plasmas radiating in the UV have been successfully used for dye laser pumping.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT: (cont)

RTOP 645-20-07. Differential Absorption with Reflection (DIAR) is performed, for aircraft applications, under a joint JPL-LRC AAFE program (RTOP 638-10-00) using a waveguide laser with limited power and tunability. Differential Absorption Lidar (DIAL) with tunable dye lasers is used by J. M. Hoell, W. Wade (LRC), and R. T. Thompson (Old Dominion Univ.) in measurements of SO_2 from a smoke stack ($\sim$2 km range) under RTOP 176-21-31. 9 Development of an optical-parametric oscillator for remote sensing ($\sim$2 km range) in the near infrared and some diffuse reflection studies of CO_2 lasers are performed at LRC with funding obtained from the EPA. For sufficiently rapid development of tunable laser and select frequency laser applications from the IR through the visible and UV for remote sensing it is essential that the effort be coordinated with strongly related laser requirements at ERDA (isotope separation, fusion) and also with NASA applications to laser communications (GSFC), and DOD applications such as optical radar and energy transmission.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers for Remote Sensing of Stratosphere, Troposphere, Shuttle Environment

14. REFERENCES: (cont'd.)

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6. S. K. Poultney, J. S. Levine, and T. McIlrath: Laser-Induced Resonance Emission from Lower Thermospheric Species. EOS Trans. 56, No. 6, p. 404 (1975).

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B-4 EARTH ENERGY BUDGET AND SOLAR IRRADIANCE MEASUREMENT EXPERIMENT

Application

The Earth-Energy Budget (EEB) and the Solar Irradiance Measurement (SIM) Experiment will have direct application to the Outlook for Space theme Prediction and Protection of the Environment (02) dealing with Climate and Climatic Changes (023), Large Scale Weather Forecasting (021), and Stratospheric Changes and Effects (024). The related applications are to the objectives of Local Weather and Severe Storm Forecasting (OFS-031), Dynamics and Energetics of Lower Atmosphere (OFS-074) and Structure, Chemistry, and Dynamics of the Stratosphere/Mesophere (OFS-075).

Payload Description

Because the character of climates, zonal and regional, can be ultimately traced to the amount and distribution of solar energy absorbed by the Earth, the following measurements are fundamental to understanding and forecasting climate change:

(1) Measurement of variations in total solar energy incident on the Earth at satellite altitude.

(2) Measurement of the distribution of net energy gained or lost by the Earth.

(3) Measurement of attenuation of radiation leaving or entering the Earth's atmosphere by man-made or natural pollution.

The payload consists of two types of instruments to make the first two types of measurements, namely, (A) measurements of the total and spectral unattenuated solar irradiance, and (B) those of upwelling radiation in the long (>4.0μ) and short (2μ-4.0μ) wavelength regions.

A. SOLAR IRRADIANCE MEASUREMENTS

It has been demonstrated that the climate changes over the past several hundred years can be explained by employing deduced variations in sun's total radiation in simple climate models. Knowledge of energy changes at specific wavelengths are also important. For example, variations at short wavelengths (less than 0.3μ) affects upper atmosphere temperatures. The relative intensities at 0.69μ and 0.74μ are important to the development of plants.

One of the science requirements is that continuous measurements of the total and spectral irradiance be made above the atmosphere as well as at ground level for at least 22 years to establish short term variations, i. e., for 11 and 22 years solar cycles. Furthermore, the total solar radiation (0.2-50.0μ) measurements are required with an accuracy of $\pm$ 0.1% and precision of 0.5%. However, the accuracy requirements for the spectral irradiance measurements are not yet accurately defined but are approximately: $\pm$5 to 10% in the (0.2-0.7μ) region, and $\pm$2 to 5% in the 0.7-3.0μ) region.

B. ENERGY BUDGET EXPERIMENT

In order to measure the distribution of net energy gained or lost by the earth's atmosphere, the two radiation streams, the albedo and the earth emitted radiation, need to be separated. One approach for separating them is to measure the total earth upwelling radiation (0.2-50.0μ) as well as the short wavelength (0.2μ-4.0μ) radiation, i. e. the albedo; the difference between the two giving the amount of earth emitted radiation.

For accurate modelling and climate prediction, more stringent accuaracies are required in separating the two streams than presently possible. For the measurement of the two streams at the top of the atmosphere, accuracy required in the case of global net radiation is better than 0.4% for albedo (short wave) and 1 w/m^2 for the long wave excitation, and in the case of regional net radiation, is better than 2% for albedo and 3 w/m^2 for long wave excitation.

Technology Advancement Required

A. SOLAR IRRADIANCE INSTRUMENTATION (TOTAL AND SPECTRAL)

Several candidate instruments exist for the measurement of total and spectral irradiance, but they need to be further developed to meet the aforementioned stringent accuracy requirements for continuous measurement from space platforms over long periods of time. These are narrow field-of-view instruments.

B. THE EE BUDGET EXPERIMENT

There are several promising candidate instruments which require further improvement in their accuracy and stability of calibration. The total type of instrument is a cavity instrument, which may require chopping for high accuracy, and hence a fast response. The instrument has a wide field-of-view.

In the albedo type instrument, there is a need for a dome/flat type filter, which requires very special attention. For example, the transmission properties of the filter are often sensitive to the angle of incidence as well as incident wavelengths. Care must be taken to take into account the possible sources of error, namely, the partially polarized earth radiation and non-scene irradiance at the thermopile brought about by differences between hemisphere temperature and the thermopile receiver temperature.

A model of the degree, orientation, and spatial and spectral distribution of polarized components of the earth radiation is required for analysis.

The requirements to the design of the sensor are required, specially to develop and test a long life cavity sensor associated with electronics and calibration procedures and to study, evolve and test new methods of separating albedo and earth emitted radiation streams.

Associated Mission Model

The Shuttle payload supports the Outlook for Space theme. The Prediction and Protection of the Environment, and especially the objectives dealing with Climate Prediction (OFS-023) and Large Scale Weather Forecasting (OFS-021).

It also supports the following 1973 Mission Model payloads.

(1) EO-3, the Earth Observatory Satellite (18 launches) 1978-91.

(2) EO-4, the Synchronous Earth Observation Satellite (8 launches) 1981-91.

(3) EO-5, Special Purpose Satellite (18 launches) 1977-91.

B-5 MULTI-WAVELENGTH ATMOSPHERIC TRANSMISSION NETWORK EXPERIMENT (MWATNE)

Application

The Multi-Wavelength Atmospheric Transmission Network Experiment (MWATNE) has application to the Outlook for Space themes: Protection of Life and Property and Prediction and Protection of the Environment, which deal with Tropsopheric Pollutants (OFS-032), and Stratospheric Changes and Effects (OFS--24), dealing with objectives of climate and weather.

The main applications of MWATNE are the measurement of the global aerosol and gaseous consituend loading of the atmosphere by performing transmissometry experiments at a network of stations, so that the effects of pollutants on climate, weather, crops, and man's health can be studied.

Payload Description

On-line absorption of radiation by the various atmospheric constituents and the off-line attenuation of radiation due to scattering by molecules and aerosols, are a sensitive measure of the distribution and concentration of the gaseous and aerosol species in the atmosphere. MWATNE is essentially an integrated system of transmissometry experiments performed simultaneously at various wavelengths (visible, IR, MW) through the whole vertical atmosphere from a network of ground stations located at various positions on the continents and oceans. For the Shuttle experiment, however, it is proposed to test this system with only a few stations (say about 10), located in the U.S. mainland and in the islands along the orbital path of the Shuttle. The post-Shuttle goal is to perform the multi-wavelength transmissometry simultaneously and continuously from a multi-satellite system covering a global network of ground stations, enabling one to get a routine continuous picture of the global distribution of the atmospheric constituents, their concentration variations, their dynamic behavior and to understand and ultimately predict how they impact on climate, weather, crops, and man's health. The proposed Shuttle experiments will thus not only serve towards the design of a simple system for continuously monitoring the natural and man made atmospheric constituents, but also check out the space flight worthiness of radiometers, detectors, coolers, filters, data processors, that are technology requirements in other space experiments.

Transmissometry can be performed in two modes: (1) sources on the space platform and detectors on the ground, and (2) sources on the ground and detectors on the space platform. Advantages of mode one are: (I) less initial cost, (II) earth emission effects are minimal, and (III) space flight worthiness of sources can be checked out during Shuttle experiments. The concern about the possible radiation hazard to human eye when IR laser sources are involved needs to be evaluated. The advantage of the second mode are (I) minimum danger of radiation damage, (II) for the visible region, the sources of light, such as search lights and warning beacons, on building tops, can be used that will also be of use of civic/safety purposes; (III) detectors, coolers, filters, etc., can be tested and optimized for space flight. The disadvantages seem to be: (I) interference from earth's surface albedo, and (II) higher initial cost of calibrated sources. One or two experiments will be designed to test which of the two modes is reliable and cost-effective.

Technology Advancement Required

MWATNE involves an integrated system of several photometers, radiometers, filters which are under proposed development in connection with other payloads. The main technology driver is to do a theoretical modelling and parametric analysis to come up with an optimum design of the network of sources and detectors and to invert the transmittance data for measuring the distribution of aerosols and gaseous (SO_2, O_3,NH_3, etc.) constituents at various locations and and altitudes in a 3-D grid.

Requirements are (1) the development of the design of a multi-wavelength (visible, IR, MW) transmissometry network; (2) development and space optimization of high resolution, long-life, calibrated sources and detectors, narrow B.W. filters and coolers ($T<100^{\circ}K$). At present the sources, detectors, filters and coolers are 1 to 2 orders of magnitude lower in performance than required for MWATNE.

Associated Mission Model

This payload supports the following 1973 Mission Model Payloads:

(1) The Earth Observatory Satellite (EO-3) which has 18 flights scheduled between 1978 and 1991.

(2) The Synchronous Earth Observatory Satellite (EO-4) which has 8 flights scheduled between 1981 and 1991.

(3) The Special Purpose Satellite (EO-5) with 18 flights scheduled between 1977 and 1991.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Multi-Wavelength Atmospheric Transmission Network Experiment (MWATNE) PAGE 1 OF ___

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Multi-Wavelength (visible, IR, MW) transmissometry network. Development and space optimization of high resolution, long-life, calibrated sources & detectors, narrow B.W. filters & coolers ($T<100^{o}K$)

4. CURRENT STATE OF ART: The sources, detectors, filters and coolers are 1 to 2 orders of magnitude lower in performance than required for MWATNE.

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

MWATNE involves an integrated system of several photometers, radiometers, λ -filters which are under proposed development in connection with other payloads. The main technology driver is to do a theoretical modeling and parametric analysis to come up with our optimum design of the network of sources and detectors and to invert the transmittance data for measuring thek distribution of aerosols and gaseous (SO_2, O_3, NH_3, etc.) constituents at various locations and altitudes in a 3-D grid.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

On-line absorption of radiation by the various atmospheric constituents and the off-line attenuation of radiation due to scattering by molecules and aerosols, are a sensitive measure of the distribution ar concentration of the gaseous and aerosol species in the atmosphere. MWATNE i. entially an integrated system of transmissometry experiments performed simul.. ously at various wavelengths (visible, IR, MW) through the whole vertical atmosphere from a network of ground stations located at various positions on the continents and oceans. For the shuttle experiment, however, it is proposed to test this system with only a few stations (say about 10), located in the US mainland and in the islands along the orbital path of the shuttle. The post-shuttle goal is to perform the multi-wavelength transmissometry simultaneously and continuously from a multi-satellite system covering a global network of ground stations, enabling one to get a routine continuous picture of the global distribution of the atmospheric constituents, their concentration variations, their dynamic behavior and to understand and ultimately predict how they impact on climate, weather, crops and man's health. The proposed shuttle experiments will thus not only serve towards the design of a simple system of continuously monitoring the natural and manmade atmospheric constituents, but also check out the space flight worthiness of radiometers, detectors, coolers, filters, data processors, that are technology requirements in other space experiments. (Cont'd.)

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** MWATNE **PAGE 2 OF** ___

7. TECHNOLOGY OPTIONS:

Ground-based experiments based on attenuation, scattering and polarization by the atmospheric constituents.

8. TECHNICAL PROBLEMS:

Stability of the calibration of sources and detectors.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Various existing RTOP's and AAFE programs for sensors and laser sources.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): MWATNE PAGE 3 OF ___

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Network Stations																			
3. Breadboard & Test																			
4. Fabrication																			
5. Final Tests																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																TOTAL
NUMBER OF LAUNCHES																

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): ____________________ PAGE OF ___

6. RATIONALE AND ANALYSIS: (Continued)

It also supports the Outlook for Space themes, Protection of Life and Property (OFS-03) dealing with Tropospheric Pollutants (OFS-032), and Prediction and Protection of the Environment, dealing with Stratospheric Changes and Effects (OFS-024).

Transmissometry can be performed in two modes: (1) sources on the space platform and detectors on the ground, and (2) sources on the ground and detectors on the space platform. Advantages of mode one are: (I) less initial cost, (II) earth emission effects are minimal, and (III) space flight worthiness of sources can be checked out during shuttle experiments. The concern about possibilities of radiation hazard to human eye when IR laser sources are involved, needs to be evaluated. The advantage of the second mode are (I) minimum danger of radiation damage, (II) for the visible region, the sources of light, such as search lights and warning beacons, on building tops, can be used that will also be of use for civic/safety purposes; (III) detectors, coolers, filters, etc., can be tested and optimized for space flight. The disadvantages seem to be: (I) interference from earth's surface albedo, and (II) higher initial cost of calibrated sources. One or two experiments will be designed to test which of the two modes is reliable and cost-effective.

SECTION C: EARTH RESOURCES SENSING PAYLOADS

C-1 COASTAL ZONE AND LAND RESOURCES MANAGEMENT

Application

This is an earth oriented, remote sensing payload which is in direct support of the Outlook For Space themes concerned with the Production and Management of Food and Forestry Resources and the Prediction and Protection of the Environment. One of the objectives of this mission is to acquire improved data to access land use, environmental factors, and living marine resources. This mission will give particular emphasis to the coastal zone which involves coastal land and wetlands use as well as coastal water quality and marine resources. The second objective is to provide a spaceflight demonstration of advanced technology applied to these important areas. This would include both advanced payload and ground truth sensing technology. The advanced technology envisioned for this spacecraft payload would involve advanced sensing concepts in multispectral imagery employing large aperture telescopes for increased spatial resolution; new spectral filtering and spectrometer concepts for improved sensitivity and selectivity; advanced all solid state electronically-scanned arrays for low cost and weight, and improved reliability and sensitivity; non-radiative coolers for increased sensitivity; and new image and electronic data processing techniques to eliminate redundancy of transmitted data. Another important aspect of this mission is the validation of these observations and measurements made from space using ground truth remote sensing systems, employing both *in situ* sensors and aircraft borne remote sensors. The aircraft remote sensing systems will provide an essential connecting link between *in situ* and space remote sensors by providing rapid surveys over large areas. Although the primary emphasis of this payload is on coastal zone observations, the advanced multispectral imagery technology demonstrated by this mission will have direct impact on other earth observation mission.

Payload Description

The payload system would employ an advanced multispectral imagery system sensitive to radiation emitted from the earth and its atmosphere over the spectral range from .2-13 micrometers. The system would provide high spectral selectivity at specific spectral locations throughout the spectral range to maximize detection sensitivity and selectivity of important land, water, and coastal zone parameters. The basic elements of this advanced multispectral imager would include a large aperture telescope; electronically-scanned, solid state detector arrays; high resolution spectral discrimination elements; a non-radiant type cooler system operating at 70^{o}K; and direct image or electronic data processors. This instrument system would be tailored to observe the most important parameters of the coastal zone and land resources management problems. Examples of important parameters that show potential for remote sensing by this payload system are:

Water and Coastal Zone

Surface temperature and thermal pollution.
Surface salinity and salt/fresh water mixing.
Chlorophyll and algae concentrations.
Industrial pollutants.
Fuel oil spills.
Turbidity and sediment distributions.
Fractional cloud cover.
Marsh plant identification.
Wetlands monitoring (dredging, filling, lagooning, damming, etc.).
Shoal mapping.
Trophic status of lakes.

Land

Mineral exploration.
Surface thermal mapping (geothermal site location, forest fire detection).
Insect population and damage surveys.
Forest coverage and cutting.
Timber classification.
Crop identification and surveys.

The precise selection of the optimum positions and widths of the instrument spectral bands needed to detect the listed parameters cannot be completely specified at present. This is an extremely important area for a continuing research program which requires extensive theoretical modelling of both physical mechanisms and systems, laboratory experimentation, and field evaluation. Based on prior research. it is possible to identify certain regions of the spectrum which will be important. The first of these is in the thermal infrared spectrum from 8 to 12 micrometers. This spectral region, which corresponds to an atmospheric window, is important for thermal mapping of both land and water surfaces and would be used to determine sea surface temperature, locate geothermal areas and conduct insect population surveys. For this experiment the desired temperature discrimination or noise equivalent temperature should be less than $.1^{o}K$, assuming a band of 10.5-12.5 micrometers is chosen. Another important use of this band is for pollutant measurements since many of the importent stratospheric and tropospheric pollutants have absorption lines in this region. These absorption lines for trace gas pollutants can be both weak and spectrally narrow and hence require special high sensitivity, high resolution spectrometric sensing techniques. The second spectral band of interest is the 3.5 to 5 micrometer band. This spectral region is useful for forest fire detection, fractional cloud cover estimation (4 micrometers) and for earth viewing through an atmospheric window (3.5 to 4.1 micrometers). Some pollutants such as CO (4.7 micrometers) and CO_2 (4.3 micrometers) have absorptive bands in this region also. The third region of interest is the 1 to 3.5 micrometer spectral range. This region also contains atmospheric windows (1.5 to 1.75 micrometers and 2.1 to 2.3 micrometers) for earth viewing and in addition has use in geological surveying such as the identification of hydrated iron oxides and clays(1.3, 1.6, and 2.2 micrometers). The fourth and richest part of the total spectrum is the .4 to 1 micrometer region. This spectral range is important for visible imagery and potentially useful for the measurement, detection, or monitoring of: chlorophyll in algae and plants ($.685 \pm .01$ micrometer); fuel oil slicks at sea (.45 $\pm$.05 micrometer); water turbidity; shoal mapping (.5 to to .6 micrometer); trophic status of lakes (.8 to 1.1 micrometer); timber, crop and marsh plant identification; wetlands changes; industrial water pollution (.6 to .7 micrometer); and insect damage. The last spectral region to be covered is the near ultraviolet band from .2 to .4 micrometers. This region is of interest for atmospheric pollutant monitoring of gases such as SO_2, O_3, and NO_2 which have strong absorption bands in this spectral range.

From the preceding discussion it should be apparent that there is enough knowledge of the important spectral characteristics of observables to begin formulation of a payload system. Continuing research in the area may ultimately change priorities and identify new spectral signatures. In spite of this, however, the underlying basic technology required to perform a mission of this type will remain unchanged. The technology development of the key elements of this advanced multispectral imager should be completed by the following target dates: large aperture telescope (1982), electronically-scanned solid state infrared arrays (1978), ultra-narrow band pass spectral filters(1980), and non-radiative coolers (1980). Based on these dates the first payload could be launched in 1983. Later launches would incorporate more advanced technology such as the Hadamard imaging spectrometer (1983) and the Fraunhofer line discriminator (1984). This schedule can be compared to the <u>Outlook for Space</u> systems <u>High Resolution and Very High Resolution Visible-IR System</u> (systems no. 2001-2004) which would directly benefit from this payload demonstration. The time frame proposed for these systems is: 2001 (1981), 2002(1982-86, 2003 (1987), and 2004 (1988-94). Since the time frames for this payload and the operational systems overlap there could be a continuous transfer of technology from this payload to the operational systems.

Technology Advancement Required

A. LARGE APERTURE TELESCOPES

An f/1.7, one meter telescope is needed for this payload system to provide a 19 fold increase in collection efficiency above present day ERTS imagery. In addition, the instantaneous field of view would be 20 microradians at .5 micrometer which would provide a factor of four improvement in ground resolution. In a near earth orbit of 200 k m this would permit a surface resolution of better than seven meters. The spatial resolution would be proportionally degraded toward the infrared and experience a factor of seven reduction at 10 micrometers. The total field of view of the optics system would be of the order of 15 degrees which would provide a 53 kim swath width on the ground. There is an important additional structural design constraint for this high resolution telescope which requires the maintenance of small deformation tolerances in the presence of space thermal loads.

B. SPECTRAL DISCRIMINATION ELEMENTS

Improved spectral discrimination elements such as filters, interferometers, and spectrometers are needed to provide increased throughput, spectral discrimination and tunability. These elements would be tailored to the parameter spectrum of interest. In particular, improved ultranarrow band pass interference filters are needed in both the visible and infrared (.3-12 micrometer) ranges to implement sensing concepts such as the Fraunhofer line discriminator imager. New spectrometer concepts such as the Hadamand Multispectral Imager need to be investigated and applied. This latter sensing concept has a potential sensitivity advantage over conventional spectrometers, while providing imagery in the 8-12 micrometer spectral band.

C. SOLID STATE DETECTOR ARRAYS

This payload system will require electronically scanned, multiple solid state detector arrays which are sensitive over the full spectral range from .2 to 13 micrometers. In order to achieve these capabilities new concepts such as charge coupled device (CCD) and charge injection device (CID) must be developed using new and different material systems. Silicon CCD technology is in a high stage of development and will cover the spectral band from .4 to 1 micrometers. Silicon CID technology is in the early stage of development, but offers improved sensitivity. Infrared CCD development for the 1 to 5 micrometer band is likewise in the early stages of development. In this spectral band InSb is being used as the detector in a monolithic CCD. The monolithic concept which is presently under investigation by NASA offers the potential of low cost, high reliability, low weight and low power consumption. An alternative approach involves a hybrid concept which uses a detector material such as PbS and InSb deposited on silicon CCD's. This latter technology will probably progress more rapidly than the monolithic approach, but does not possess the advantages of the former. In the 5 to 12 micrometer band ternary material detectors such as HgCdTe appear promising. Work is needed in this area to improve detector detectivity (D*) at higher operating temperatures so that space system cooling requirements can be reduced or eliminated. In the 8-12 micrometer band a class of pyroelectric detectors offers the potential advantage of high temperature operation with acceptable D* values. At present there is no known research in progress on self-scanned solid state arrays in the 8-12 micrometer band. Finally, these detector arrays would have 13,100 elements of approximately 30 micrometers on a side to meet the instantaneous and total field of view requirements.

D. COOLERS

Space qualified non-radiative type coolers which will reach temperatures in the range from 70 K (1 watt) to 100 K (10 watts) are needed for detectors and optical components operating in the thermal infrared region of the spectrum. This advance is needed to improve overall system sensitivity. In situations where the detector is the major noise source a tradeoff can be made between cooling requirements and improved detector performance, i. e., as detector performance is improved cooling requirements can be reduced. Analytical studies to investigate potential cooler designs are in progress.

E. IMAGE PROCESSING

Techniques to reduce the flow of redundant information need to be developed. One approach to this is to perform direct image processing using Fourier transform imagery which could perform pattern recognition, data compression and spatial frequency analysis. This advanced technique is in the early research stage. Another near real-time processing of multispectral imagery data. Faster microprocessors need to be developed before this technology can be applied.

F. GROUND TRUTH SUPPORT SYSTEMS

The successful validation of multispectral imagery and measurements from space will to a large extent depend on synoptic ground truth data. This will require both *in situ* ground-based sensors and aircraft instrumented with remote [illegible] *situ* sensors which can observe large land areas in a short period of time. [illegible] remote sensing instruments would bridge the gap between more accurate point measurement *in situ* sensors at fixed locations and the large area coverage provided by the spacecraft multispectral imagery. Remote sensing and *in situ* instruments are needed for every parameter of interest. Several examples applicable to coastal zone observations are included in the listing of technology requirements. Two of these are airborne remote sensing instruments employing laser techniques for the measurement of ocean and estuarine salinity and turbidity. The laser technique (Raman LIDAR) is the only known technique that has potential for remote subsurface (> 1 meter) salinity measurement. Similar techniques are under development for algae chlorophyll concentration measurement and oil slick detection. These systems are in the development stage. The third instrument is called the Multispectral Ocean Color Sensor (MOCS) and is in the flight evaluation stage. This instrument, a multispectral imager, is used for observing selected signatures from the water parameters such as pollution, chlorophyll, etc. The fourth instrument listed in the technology requirements is an in situ multispectral imager based on a Viking facsimile camera concept. This would find application for high resolution verification of multispectral images generated by the spacecraft imager.

Associated Mission Model

Advanced technology demonstrated by this payload would support multispectral imagery missions in the following areas:

Timber Inventory (015)
Control of Harmful Insects (036)
Rangeland Assessment (016)
Global Crop Production (011)
Large Scale Weather (021)
Stratospheric Changes and Effects (024)
Local Weather and Severe Storm Forecasting (031)
Tropospheric Pollutants Monitoring (032)

In addition, it is in direct support of the Outlook for Space systems High Resolution and Very High Resolution Visible-IR System (Systems no. 2001-2004).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Imaging Optics for Coastal Zone Management

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop low f/#, wide angle field of view, imaging optics for high spatial resolution multispectral imagery (.4 - 12μ)

4. CURRENT STATE OF ART: ERTS imagery 0.4 to 1.1μ, 76 micro radian resolution, NOAA 3 Radiometer, 600 micro radian resolution, 9" and 5" diameter optics.

HAS BEEN CARRIED TO LEVEL 9

5. DESCRIPTION OF TECHNOLOGY

Requirement: 20 micro radian resolution at .5μ

150 micro radian resolution at 10μ

Casegranian Optics technology to obtain these resolutions is given in attached table taken from reference #1. Optics diameters of 0.5 to 1 meter are required. Necessitates large volume payloads. Light weight and high dimensional precision optics technology is required.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. High spatial resolution imagery is needed for Earth resources monitoring. Large diameter optics are required because of diffraction limited effects.

2. Monitoring coastal zone esturines, wetlands, pollution, commerce require high resolution multispectral imagery.

3. Large diameter optical systems evaluation compatible with shuttle payloads.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ______________ PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Fly lower resolution radiometers on aircraft.

8. TECHNICAL PROBLEMS:

1. Weight, dimensional stability of optics materials.
2. Optical design to cover large wavelength range and large angular field of view.
3. Extreme mechanical precision need for scanning techniques.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

GSFC. Scanning Spectroradiometer program (Image plane scanner, 16" dia. collecting optics, 30 microradian resolution) 3 study contracts.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

1. Optical materials of light weight configuration needed.
2. Solid state detector arrays, image scanning technique and spectral filters technology must integrate with imaging optics to provide complete system.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ______________ PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses		—																	
2. Design			—																
3. Fabrication				—															
4. Space Checkout					—	—													
5.																			
APPLICATION																			
1. Design (Ph. C)						—	—												
2. Devl/Fab (Ph. D)								—											
3. Operations									—	—									
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE								Δ									TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. Point Design Study Scanning Spectro-Radiometer Te Company Contract, NAS5-21948 Final Report #1046-1 August 1973.

2. Design Study Report Seven-Band Scanning Radiometer Honeywell Contract #NAS5-21757, January 1973.

3. Scanning Spectroradiometer Point Design Final Report Hughes Contract #NAS5-21952, September 1973.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

TABLE 2-9. FACTORS AFFECTING SPATIAL RESOLUTION

θ_{I_L} Image Size, mr												
	Diffraction Effects 90 Percent of Energy Contained Within			Mirror Figure Accuracy			Primary Secondary Misalignment to Optical Axis 0.002 Inches	Focal Plane Misalignment by 0.001 inch	Thermal Gradient ‖ to Optical Axis. Spacer $\Delta T_1 = 2°C$ Secondary Mirror $\Delta T_2 = 4°C$	Summation of Effect $\left[\sum_{i=1}^{7}(\theta_{I_D})_i^2\right]^{1/2}$		
Diameter, inches	0.5 micron	2.5 microns	11.5 microns	Scan 1λ across major dimension	Primary λ/2 deviation	Secondary λ/4 deviation				0.5 micron	2.5 microns	11.5 microns
6	0.021	0.106	0.489	0.0133	0.0267	0.0267	0.02	0.019	0.014	0.0546	0.1173	0.492
9	0.0142	0.071	0.327	0.0089	0.0178	0.0178	0.013	0.0128	0.014	0.0378	0.079	0.329
12	0.0106	0.053	0.244	0.0067	0.0133	0.0133	0.01	0.0096	0.014	0.030	0.060	0.246
16	0.008	0.04	0.184	0.005	0.01	0.010	0.0075	0.0072	0.014	0.024	0.046	0.185
20	0.0064	0.032	0.147	0.004	0.008	0.008	0.006	0.0058	0.014	0.021	0.0378	0.148

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Hadamard Multispectral Imager — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Design and develop a thermal IR imager using the Hadamard Transform/multiplexing advantage to improve sensor detection signal to noise ratio.

4. CURRENT STATE OF ART: Thermal IR detectors and object plane scanning radiometers provide 1 km resolution, + $2^{o}K$ sensor accuracy, and use an 8-12μ spectral band.

HAS BEEN CARRIED TO LEVEL 9

5. DESCRIPTION OF TECHNOLOGY

The Hadamard Transform Spectrometer imager uses a single detector which senses a large portion (50%) of the total scene energy continuously during a mission, thereby giving an optical multiplex advantage. A multiaperture, encoded graticule is scanned across the image in the usual radiometer optics. The graticule encoding and detector outputs are fed simultaneously into a computer which inverts the data with a Hadamard Transform to reproduce an image of the scene. By including a grating spectrometer in the system, imagery in different spectral bands can be provided. By selecting several bands within the 8 to 12μ spectral range, more accurate temperature information may be obtained about the scene.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. The multiplex advantage provides a larger S/N ratio and eliminates the image scanning mirrors of a normal object plane scanned with multiple detectors.
2. Provides thermal IR imagery in the 8-12μ wavelength bands. Multispectral capability will provide for greater temperature measurement accuracy, ± $0.1^{o}K$.
3. Useful in coastal zone water pollution measurements, Shuttle, Seasat, etc.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.**

1. TECHNOLOGY REQUIREMENT(TITLE): ______________________ **PAGE 2 OF 3**

7. TECHNOLOGY OPTIONS:

Frequency modulated graticules scanned in image plane.
Requires multiple demodulation and multiplexing circuits.

8. TECHNICAL PROBLEMS:

1. Efficiency of detector collecting optic need to be improved.
2. Minimum size of graticule elements influence size of optics in high resolution radiometers.
3. Requires wide angle, low F/#, high resolution collecting optics.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP # 176-13-33-02 Water Quality and Pollution Sensing -
Evaluate Breadboard Model from AAFE Development.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of: data inversion of Hadamard code using mini computers, data display and recording techniques, thermal IR standards and calibrations techniques.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.
1. TECHNOLOGY REQUIREMENT (TITLE):	PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Design																			
3. Fabrication																			
4. Space Checkout																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE								Δ									
NUMBER OF LAUNCHES																	

14. REFERENCES:

AAFE contract #NAS1-12690

"AS&E Hadamard Imaging Spectrometer Development

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Fraunhofer Line Discriminator Imager (FLDI) PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensor and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Design and Develop an Imaging FLD for Space Application

4. CURRENT STATE OF ART: Non-imaging helicopter flight model has been developed and flight tested

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

Large diameter collecting optics and object plane scanning system is to be adapted to the present nonimaging FLD concept to provide imaging from space. Narrow band filters and double beam photometry techniques are combined with the above imaging optics to sense the luminescence of certain earth targets within the Fraunhofer absorption lines of the solar spectrum.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. Cross track scanning from a sun synchronous orbit can provide imagery (1 km footprint) of earth resources materials and pollutants (Chlorophyll, oils, phosphates, etc.).

2. Can be useful in coastal zone pollution monitoring, plant stress in forestry, mineral detection in geology.

3. Image contrasts are enhanced for materials luninescence beyond that normally found in material reflectance for some fluorescent materials.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** ______________ **PAGE 2 OF 3**

7. **TECHNOLOGY OPTIONS:**

8. **TECHNICAL PROBLEMS:**

1. Intervening atmospheric scattering cause contrast reduction and not operable in presents of clouds.

2. Study possible single beam rather than double beam photometry techniques.

9. **POTENTIAL ALTERNATIVES:**

None.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

None.

EXPECTED UNPERTURBED LEVEL ___

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Narrow band filter development.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ______________ PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Design																			
3. Fabrication																			
4. Test																			
5. Space Checkout																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. FLD Engineering Model of Helicopter - AAFE Program
2. Proposal for Operational Fraunhofer Line Discriminator (FLD) Application Study - Perkin-Elmer #11743, 12 November 1973

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREA[illegible]ARD TESTED IN RELEVANT ENVIRONMENT IN [illegible] LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Direct Fourier Transform Imager PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Permit the immediate utilization of multiplex (Fourier) advantage as well as permit Fourier data processing on raw image

4. CURRENT STATE OF ART: ____

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The Direct Fourier Transform Camera consists of an acousto-electrical light detector whose output in a Fourier transform of the input radiant intensity distribution. The technique consists of launching acoustic waves down a photosensitive slab. Nonlinear interaction between photons and acoustic waves causes a multiplication between the two. Electrical current flowing transversely to acoustic wave is proportional to the Fourier component of the image at that acoustical wavelength frequency scanning completes the generation of the Fourier transform.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The ability to do pattern recognition, to do data compression, to utilize multiplex advantages for signal-to-noise ratio, and to do frequency analysis of imagery data are all capabilities that current imaging systems do not possess. At present a standard image must be generated and then either digital or holographic techniques must be employed. The Direct Fourier Transform Imager has the potential to bridge the gap between the conventional imager and the data processor.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Direct Fourier Transform Imager

7. TECHNOLOGY OPTIONS:

Technology options include selection of materials, optimization for various wavelength bands, and utilization of various acoustic generators.

8. TECHNICAL PROBLEMS:

Nonlinearities must be fully explored as well as the ability to launch properly terminated travelling waves. Signal-to-noise must be fully understood.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None.

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Direct Fourier Transform Imager PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

Deft: Direct Electronic Fourier Transforms of Optical Images, Kornreich, P. G., et al.; Proceedings of IEEE, August 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Ultra Narrow Band Filter for Remote Sensing PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Design and develop infrared bandpass filters of the Fabry Perot Interference type to advance the capability of IR spectroradiometers for the detection and measurement of line strengths in molecular spectra.

4. CURRENT STATE OF ART: Visible filters have been carried to level 6 (Fraunhofer Line Discriminator Program). IR filters are in the early design phase.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Ultra narrow band filter requirements for atmospheric absorption experiments:

Wavelength range: 5μ to 20μ (2000 cm^{-1} to 500 cm^{-1})

Full width, half max. range: $3 \times 10^{-4}\mu$ to $1 \times 10^{-3}\mu$ (0.12 cm^{-1} tp 0.025 cm^{-1})

Transmission: 0.50

Optical ray cone angle: 2°

Operating temp.: $80^{\circ}K$

By tilting the filter, limited wavelength tuning can be accomplished to scan several spectral lines in the IR spectrum.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. Filters to be incorporated into a differential absorption spectroradiometer to measure atmospheric gas composition and pollutants.

2. Global coverage of the Earth environment from air-Sat or Shuttle.

3. Provides greater spectral specificity and detection capability over present broadband filters used in LRIR or proposed LACATE sensors.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ______________ PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

IR Laser tuning techniques may accomplish same measurements in differential absorption spectrometry.

8. TECHNICAL PROBLEMS:

IR Material selections, design for specific wavelength filters, wavelength shifts with filter temperature change, integration of filter and detector into compatible sensing subsystem.

9. POTENTIAL ALTERNATIVES:

Useful as a blocking filter in laser tuning differential absorption spectrometry.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Requires use with large diameter collecting optics (1 meter) and cooled detector filter subsystem.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ______________

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Design																			
3. Fabrication																			
4. Ground Task																			
5. Space Checkout																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE							Δ											
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
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8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Optimize detectivity, response time and operating temperature.

4. CURRENT STATE OF ART: In the 1-14 micrometers range, II-VI and III-V, semi-conductor detectors have detectivities above 10^{10} cm-Hz$^{\frac{1}{2}}$-watt^{-1} but require cooling to 80°K. (See p. 4.) HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

The III-V and II-VI semi-conductor detectors are available in photo-conductive devices or photovoltaic devices. From 1-5 micrometers, binary compounds will suffice. Above 5 micrometers, the peak response as a function of wavelength can be varied in a II-VI ternary compound (for example, $Hg_x\ Cd_{1-x}\ Te$ and $Pb_x\ Sn_{1-x}\ Te$) by changing the ratios of the group II constituents.

A pyroelectric detector consists of a slab of pyroelectric material having two opposite face areas coated with conductive layers to form a capacitor. A change in temperature generates a signal current proportional to the pyro-electric coefficient. To optimize the signal, a material should possess a low heat capacity, low dielectric constant, and large pyroelectric coefficient. Since the signal current is proportional to the rate-of-change of the temperature, this detector is more attractive than other types of uncooled thermal detectors for higher frequency applications.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

These devices are used for remote sensing in earth resources missions, environmental pollution monitoring, and thermal mapping.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Infrared Detectors for Remote Sensing

7. TECHNOLOGY OPTIONS:

The detectivity of the II-VI ternary compc nds can be increased to the point where it is practical to operate these devices at higher temperatures than 80°K. The detectivity of the pyroelectric can be increased to $\sim 10^{10}$cmH watt^{-1}.

8. TECHNICAL PROBLEMS:

1. Control of honogeneity in III-V and II-VI materials restricts array construction.
2. Poor reproducibility of detector parameters in III-V and II-VI materials.
3. Relatively low operating temperature (∿80°KO in the II-VI ternary materials.
4. Relatively low detectivity in pyroelectric detectors (Cont'd., p. 4)

9. POTENTIAL ALTERNATIVES:

If temperatures on the order of 85°K can be achieved for the desired mission, it is suggested that doped silicon detectors be employed because of their higher detectivity in the wavelength range greater than 5 micrometers. In addition, the detector preamplific: can be directly incorporated with the device.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP # 506-18-21, "Electronic Devices and Components," contains elements bearing on this technology, such as an indium antimonide CCD sensor and pyroelectric detector materials investigations.

EXPECTED UNPERTURBED LEVEL 8

11. RELATED TECHNOLOGY REQUIREMENTS:

Advancement in preamplifier performance technology: improved material growth technology: small volume, low power cooling systems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY:																			
PYROELECTRIC DETECTORS:																			
1. Elec. Component Des.																			
2. Component Development																			
3. Array or CCD Hybrid Fabrication																			
4. Space Checkout																			
III-V & II-VI Compound DETECTORS:																			
1. Materials Growth																			
2. Detector Fabrication																			
3. Analysis																			
4. Ground Checkout																			
5. Space Checkout																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. "Infrared Technology for Remote Sensing," Special Issue, Proceedings of the IEEE, 63, No. 1 (1975)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing PAGE 4 OF 4

4. CURRENT STATE OF ART: (cont'd.)

Over the wavelength range 1-20 micrometers, pyroelectric detectors have a relatively low detectivity ($D^* \simeq 5 \times 10^8$ cm-$Hg^{\frac{1}{2}}$-watt^{-1}) but require little or no cooling.

8. TECHNICAL PROBLEMS: (cont'd.)

5. Relatively long response times in pyroelectric detectors which restricts their practical operating frequency.
6. Pyroelectric detectors highly sensitive in vibrations.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Intensified Solid State Imaging Device PAGE 1 OF ____

2. TECHNOLOGY CATEGORY: Imaging

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop a low light level solid state imaging device by integrating a "CID" imaging device with an imaging intensifier.

4. CURRENT STATE OF ART: CID devices have been built but have not been integrated with image intensifiers

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

A technique for increasing the sensitivity of "Charge Injected Devices" (CID) imaging devices in order to more completely take advantage of their ruggedness, size, weight, and low power consumption. These devices will be strong competitors for present low light level tube type systems.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) As the resolution of the solid state devices increase, devices such as the CID will replace tube type imaging devices. In addition, as the sensitivity of CID type devices is increased, by integration with intensifiers, intensified CID's could replace tube devices on the LST and Spacelab.

(b) The great advantages of the solid state imaging devices are:
1. Elimination of a heater element
2. Very small size, compared to an equivalent tube device.
3. Light weight.
4. Ruggedness, due to the elimination of electrodes.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Intensified Solid State Imaging Device PAGE 2 OF

7. TECHNOLOGY OPTIONS:

(a) Continued development and improvement in tube type imaging devices.

8. TECHNICAL PROBLEMS:

(a) Contamination of the CID silicon chip by materials from the intensifier photocathode.

(b) Damage to the CID by high energy particles within the system.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Intensified Solid State Imaging Device PAGE 3 OF ___

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis & Design																			
2. Fabricate Test Model																			
3. Test																			
4. Evaluation																			
5. Report: Results																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Imaging Devices Based on Charge Coupled Device Concepts (Hybrid and Monolithic) PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Infrared Sensors and Imagers

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased Spectral Resolving Power, Angular Resolving Power as well as Increased Sensitivity with Additional Features of on Chip Signal Processing and Flexibility of Signal Manipulation.

4. CURRENT STATE OF ART: Hybrid infrared CCD devices are in the development stage (1-12 micrometers) and system problems are being worked. Monolithic devices are in the first stages of research. HAS BEEN CARRIED TO LEVEL 5/4

5. DESCRIPTION OF TECHNOLOGY Hybrid Infrared CCD devices are infrared detectors mated to silicon CCD signal processors. Basic problems concern the design of the coupling method of the detectors to the silicon CCD in a sandwich type arrangement on the focal plane of an optical system. Signal processing, timing sequence, background, dynamic range, and uniformity of response are being worked in both a materials and a systems sense. In monolithic infrared CCD devices the entire MIS (metal-insulator-semi-conductor) fabrication process is being worked for compatibility and stability of detectors, FET's, diodes and CCD development. The state of the art being that charge transfer has just been demonstrated for the first time in the InSb infrared detector material. Basically the technology is that of developing a silicon LSI process for the infrared material being used that satisfies all the microelectronic fabrication requirements as well as the infrared detector response requirements.

Hybrid infrared detector systems currently being developed by the DOD are InSb and HgCdTe. With research underway by numerous groups on the hybrid detectors such as PbS, Pyroelectric devices, etc. The only monolithic R & D has been in Insb.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS: These devices are of the Focal Plane Array types utilizing the low cost, high reliability, minimal size, weight and power consumption associated with the micro-electronic concepts LSI silicon technology. These devices offer a new concept in increased sensitivity utilizing the Time Delayed Integration (TDI) concept (a signal summation process where the S/N ratio has been shown to increase by the N; where N is the number of detectors). In addition due to signal processing capabilities on the chips increased versatility and complexity of signal manipulation is gained as well as decreased capacitance of the devices which usually decreases the overall noise of the system. Infrared systems provide a day and night time measurement capability.

Requirements for devices of the above types are based on new and improved infrared measurement techniques needed in the following categories:

A. Infrared Imaging for Geological Experiments Concerning Classification and Typing of Mineral Deposits in the Exploration of New Mineral Resources Throughout the World.
B. Atmospheric Temperature Sounding for Weather Forecasting utilizing the 4.3 micrometer CO_2 Band.
C. Estimate of Fractional Cloud Cover in distinguishing between clouds and water surfaces in both the day time and night time (maximum difference between cloud and water surface emittance occurs near 4 micrometers).

(Cont'd. on p. 4) TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Infrared Imaging Devices Based on Charge Coupled Device Concepts (Hybrid and Monolithic)

7. **TECHNOLOGY OPTIONS:**

The alternative approach would be to continue to develop systems of single detectors which utilize a rocking mirror. TDI could be utilized which would increase the detector sensitivity. No alternative system approach exists that offers the versatility and promise of performance improvements that is comparable to hybrid or monolithic infrared imaging devices based on CCD concepts.

8. **TECHNICAL PROBLEMS:**

1. Fabrication of the monolithic MIS structures.
2. Identification of MIS monolithic devices with low interface state densities.
3. Development of readout devices, FET's, diodes, etc. in monolithic systems.
4. Fabrication of a hybrid monolithic sandwich structure utilizing detectors and silicon CCD's.
5. Reduction of noise problems due to lead in contacts from detectors in Hybrid system.
6. Determination of clocking sequences, signal condition and processing technology.

9. **POTENTIAL ALTERNATIVES:**

Utilize multiple wavelength scanning by prisms or diffraction grating after scan achieved with rocking mirror or scanning mirror concept.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

RTOP # 506-18-21 "Electronic Devices and Components" has a current modest level of funding for the development of monolithic infrared imaging devices based on CCD concepts. Work in this area could easily be expanded to develop a specific hybrid infrared CCD infrared imaging system for the 1-5 micrometer region which could be available for an experimental flight for one of the above mentioned categories of experiments in approximately 3-4 years. Increased funding would of course be needed.

EXPECTED UNPERTURBED LEVEL 5

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Increased data handling capabilities would be needed to handle expected increased infrared imaging data that would be available in terms of a variety of spectral information as well as increased elemental ground resolution. Night time data would also be available which would increase the data handling requirements. Due to the signal processing capabilities of CCD structures, increased complexity of systems might be required if on board data processing were undertaken to decrease the amount of data transmitted back to earth.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Imaging Devices Based on Charge Coupled Device Concepts (Hybrid and Monolithic) PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
(Monolithic)																			
1. Analysis of Structure																			
2. Improved design																			
3. Linear Array Fab.																			
4. Ground Checkout																			
5. Aircraft Evaluation																			
(Hybrid)																			
1. Device Design & Fab.																			
2. System Design & Fab.																			
3. Dev. & Sys. Integrate																			
4. Aircraft Evaluation																			
APPLICATION																			
1. Geology Experiments																			
2. Atmos. Temp. Sounding																			
3. Pollution Mapping																			
4. Planetary Astronomy																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. Infrared Detectors in Remote Sensing, H. Levinstein and J. Mudar, Proceedings of the IEEE, January 1975, page 6.

2. Imaging Devices Using the Charge Coupled Concept, D. F. Barbe, Proceedings of the IEEE, January 1975, page 38.

3. Application of Charge Coupled Devices to Infrared Detection and Imaging, A. J. Steckl, R. D. Nelson, B. T. French, R. A. Gudmundsen, and D. Schechter; Proceedings of IEEE, January 1975, page 67.

4. Charge Coupled Infrared Imaging Device (CCIRID) Feasibility Study, NASA CR-134183, December 1973, R. D. Thom and R. E. Eck.

5. Symposium on Charge-Coupled Device Technology for Scientific Imaging Applications, JPL SP 43-21, March 1975.

6. Proceedings of IEEE, Special Issue on Infrared Tech. for Remote Sensing.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Imaging Devices Based on Charge Coupled Device Concepts (Hybrid and Monolithic)

6. RATIONALE AND ANALYSIS:

D. Pollution Sensing of Pollutants Spectral Signatures at Various Wavelengths.

E. Planetary Astronomy Spectral Imaging such as 5 micrometer Methane bands of Saturn.

F. Spectral Infrared Imaging Applications 1-20 micrometers region.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Optimization of Infrared Radiation Detection PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Infrared Detectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reduction of low temperature operational requirements for infrared detectors

4. CURRENT STATE OF ART: Low noise tri-metal detectors - operate at temperatures no higher than 90°K as typified by S191 on Skylab.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

To generate usable signals in long wavelength infrared detectors, the detector must be cooled to temperatures near 77°K. Operation at higher temperatures is limited because of the presence of inherent thermal noise. Frequently, the cooling process introduces a significant amount of noise. The use of liquid nitrogen cooling is inconvenient, and can be hazardous to personnel. It is suggested that a low-noise, moderate temperature detector may be developed through a methodical computer aided research program in terms of general material, environmental, and impurity considerations such as band structure, transport properties, and temperature.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Relaxed temperature requirements for infrared detectors are required so that weight and power consumption required for cooling may be reduced and flexibility may be expanded.

(b) Low altitude and orbital earth observation remote sensing systems will benefit from this technology.

(c) Mechanical refrigerators of liquid nitrogen cooling devices severely limit the flexibility and the operating time of infrared detection systems.

(d) This technology advancement will be a new capability derived from present infrared detector technology.

TO BE CARRIED TO LEVEL 2

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Optimization of Infrared Radiation Detection

7. TECHNOLOGY OPTIONS:

An alternative to moderate temperature detectors would be to find a suitable means of cooling detectors to low temperatures by non-mechanical means such as by cryogenic adsorption pumping techniques. This type system would be closed cycle and free from the noise generated by a mechanical pump.

8. TECHNICAL PROBLEMS:

1. Processing or fabrication problems.
2. Environmental considerations.
3. Mathematical expression of a generalized detector.

9. POTENTIAL ALTERNATIVES:

Investigate detector characteristics as related to fundamental material properties separately as well as in combination.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL 2

11. RELATED TECHNOLOGY REQUIREMENTS:

Low-noise pre-amplifiers

Design cryogenic refrigerators with less stringent cold temperature requirements.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Optimization of Infrared Radiation Detection

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis	—																		
2. Mathematical Model		—																	
3. Fabrication Techniques Developed			—																
4. Fabrication				—															
5. System Integration				—	—														
6. Testing & Documentation					—	—													
APPLICATION																			
1. Design (Ph. C)						—													
2. Devl/Fab (Ph. D)							—												
3. Operations								—	—	—	—	—	—	—	—	—	—	—	
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES								2	2	3	4							11

14. REFERENCES:

(1) Infrared System Engineering by Richard D. Hudson, Jr., 1969

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Near Infrared (1 to 8 μ) Imaging Sensor Development for Multispectral Imaging for Planetary and Terrestrial Applications

2. TECHNOLOGY CATEGORY: Improved Sensor and Detector Technology

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop hybrid CCD line and area array detectors which have the desired infrared detector such as PbS, InSb, etc., deposited on the photosensitive area of the CCD.

4. CURRENT STATE OF ART: Custom hybrid detectors of this nature have been produced for military application by several companies (including Hughes, SBRC, and TI).

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

Although several companies are working on hybrid CCD detectors with near-infrared sensitivity, no detectors suitable for multispectral imaging applications for planetary and Earth application flight hardware are available.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. A hybrid CCD detector which has sensitivity in the 1 to 8μ spectral region coupled with specific on-board spectral filtering, ratioing, or similar on-board processing has the advantage of strong absorption and radiative characteristics for many multispectral imaging applications.

b. Both Earth and planetary multispectral imaging application can utilize this extended spectral region and at the same time have the advantages of the CCD processing logic, the large dynamic range, and optimum quantum efficiencies. Shuttle payloads and some planetary instruments proposed for LPO and "JU would utilize this technology.

c. The advantages of the CCD in low-power, low-weight, high-sensitivity sensor technology could be complemented with the extended spectral sensitivity range offered by the hybrid CCD detector.

d. This technology advancement should be incorporated into specialized multispectral imaging and analysis systems which could be experimentally demonstrated on an early Shuttle flight. This Shuttle experience would be used to optimize instrumentation for Lunar and Planetary investigation applications.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Near Infrared (1 to 8μ) Imaging Sensor Development for Multispectral Imaging for Planetary and Terrestrial Applications

7. **TECHNOLOGY OPTIONS:**

These hybrid CCD detectors using the strong signatures of many surface materials and atmospheric absorptions in the near-infrared could be incorporated in systems which incorporate simple on-board processing to enhance the present multispectral imaging systems.

The present development of higher resolution non-CCD linear diode arrays with sensitivity in the near-infrared ultimately is limited by the number of individual wires which can be attached to an individual chip. The efficient on-chip amplification and readout capabilities of the CCD, can simplify the design of these instruments and at the same time, keep the low-power and low-weight helpful parameters.

8. **TECHNICAL PROBLEMS:**

These detectors may be radiation sensitive.

9. **POTENTIAL ALTERNATIVES:**

Technical alternatives involve the use of image converters and intensifiers with special photosensitive surfaces. This well-known technology is not condusive to low-power, light-weight system design.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

RTOP # ________________ "Specialized Multispectral Imaging and Analysis System" could be expanded in scope to incorporate the near-infrared hybrid CCD detectors.

EXPECTED UNPERTURBED LEVEL 5

11. **RELATED TECHNOLOGY REQUIREMENTS:**

CCD Detector Technology On-Board Processing

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Near Infrared (1 to 8μ) Imaging Sensor Development for Multispectral Imaging for Planetary and Terrestrial Applications PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

Proceedings of the Symposium on CCD Technology for Scientific Imaging Applications, March 6 and 7, 1975.

Various publications by Alex Goetz.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Radiative Refrigeration Design PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Infrared Detector Refrigeration

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased sensitivity of infrared systems used in orbital applications for remote sensing of environment.

4. CURRENT STATE OF ART: Several designs for passive systems have been used, but evaluations and design tasks have not been attempted for lack of opportunity. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The sensitivity of infrared detectors is dependent on the attainment and maintenance of very low temperatures - near liquid nitrogen. The practical approach to this requirement for long term missions is to utilize passive radiative refrigeration systems. The operation of these hinges on the temperature difference between outer space and the object requiring cooling. Several designs have been used in an attempt to accomplish the required results. These efforts have met with moderate success. A new system based on a comprehensive evaluation of current approaches concurrent with a design effort would provide increased infrared detection sensitivity.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Currently used infrared detectors require temperatures in the range of 80 degrees kelvin.

(b) Development of this system would benefit satellite designs of the ERTS-C type. In some applications, the Themmatic Mapper would benefit.

(c) Present designs provide temperatures in the 195°K range with theoretical predictions down to about 100°K. Improvements would result in greater ground target thermal resolution, probably by an order of magnitude.

(d) This technology advancement should be carried to an experimental demonstration in an early Shuttle flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Radiative Refrigeration Design **PAGE 2 OF 3**

7. TECHNOLOGY OPTIONS:

The effectiveness of passive refrigeration devices relate to the ability of the system to radiate into outer space. This is a materials, as well as a geometry problem. It is proposed that a pallet of several designs be simultaneously evaluated in a modular/adjustment configuration permitting real-time interactive modifications.

8. TECHNICAL PROBLEMS:

1. Thermal path between infrared detector and refrigeration system.
2. Ability of system to radiate into outer space (Radiator Design).
3. Pointing of system into outer space.

9. POTENTIAL ALTERNATIVES:

Possibly using adsorptive pumping techniques using solar energy for power input in a conventional refrigeration cycle.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Current research by JSC for development of adsorption pumping techniques for use in cryogenic refrigeration purposes.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Infrared detector technology, low temperature technology, remote sensing technology.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Radiative Refrigeration Design PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Mechanical & Thermal Design																			
3. Fabrication																			
4. Test																			
5. Documentation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE						4												
NUMBER OF LAUNCHES						2	3	2	1									8

14. REFERENCES:

"Infrared System Engineering" by Richard D. Hudson, Jr. 1969

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Near-UV (200 to 400 nm) and Visible Multispectral Imaging Investigations for Terrestrial Pollution and Planetary Atmospheric Measurements PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: Photo-Detection of Atmospheric Pollutants

3. OBJECTIVE/ADVANCEMENT REQUIRED: Use multispectral imaging to attempt photo-detection of atmospheric pollutants such as SO_2.

4. CURRENT STATE OF ART: Laboratory spectral data illustrate the signature of several gases including SO_2, O_3, and NO_2, which have strong absorptions in the near-UV and visible.

HAS BEEN CARRIED TO LEVEL ____

5. DESCRIPTION OF TECHNOLOGY

This technology would be to identify stationary sources of emissions detectable by near-UV spectral imaging which can possibly be correlated with atmospheric pollution.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The near-UV spectral imaging is an area of scientific investigation that has had very little previous investigation.

(b) The Mariner 10 images of Venus taken in the near-UV give a striking example that UV imaging is a viable means of gathering atmospheric data.

(c) By expanding the multispectral techniques currently being carried out under RTOP 645-30-08 to the near-UV, this task could easily be demonstrated on an early Shuttle flight, since the system could be built up with existing technology.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT (TITLE):** Near-UV (200 to 400 nm) and Visible Multispectral Imaging Investigations for Terrestrial Pollution and Planetary Atmospheric Measurements **PAGE 2 OF 2**

7. **TECHNOLOGY OPTIONS:**

8. **TECHNICAL PROBLEMS:**

Ultraviolet requires stricter cleanliness in overall handling in order to ensure organic contaminants do not mask out potential signal.

9. **POTENTIAL ALTERNATIVES:**

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

EXPECTED UNPERTURBED LEVEL __

11. **RELATED TECHNOLOGY REQUIREMENTS:**

DEFINITION OF TECHNOLOGY REQUIREMENT   NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Multispectral Ocean Color Sensor (MOCS)   PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of a MOCS optimized for space flight, increase spatial resolution, select spectral bands to fit water target spectral signatures.

4. CURRENT STATE OF ART: Aircraft MOCS flight tested-20 spectral channels-low spatial resolution-ground truth calibrated for some water targets.

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

Multispectral Imaging Radiometer [illegible] lens radiation collector, diffracting grating radiation dispersing system, image disector cathode ray tube detector, electron beam scanning, cross track scanning to provide spatial imagery, 20 spectral bands, spectral range 0.4 to 0.8 microns, no moving parts, fast scan rate, high signal to noise ratio for water targets. Enhances spectral and radiance contrast of weak gradients in water reflectance characteristics. Allows detection of pollution, algae, sediment, surface anomollies, etc.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Current MOCS program is developing water signature and water related target spectral radiance signatures. This work relates to ocean and coastal water targets including pollution, sedimentation, algae, chemicals and toxic waste, oil, etc. This information will provide the above requirements for the development of an advanced space flight MOCS. Development of sensors, data analysis techniques and display methods should be carried to completion for evaluation on Shuttle.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ______________

7. TECHNOLOGY OPTIONS:

Use presently developed aircraft MOCS.

8. TECHNICAL PROBLEMS:

1. Design of high resolution optics: angular resolution 800 microradians.
2. Define and reduce number of spectral bands based on aircraft data analysis.
3. Develop mathematical algorithms and data display technique fast automatic computer system.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP # 176-13-33 Aircraft sensor flight evaluation.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ______________ PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Design																			
3. Fabrication																			
4. Space Checkout																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE							Δ											TOTAL
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Coastal Zone Resource Imager PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Permit low earth orbit monitoring of coastal zone characteristics by an instrument optimized for such measurements, utilizing solid state detectors only.

4. CURRENT STATE OF ART: Instruments exist which can measure some of the desired characteristics but no coordinate instrument exists for coastal zone.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The coastal zone resource imager consists of a four part imaging system, all solid state. Part one is a visible color and false color IR section (0.4 μ to 1.1μ) high resolution imager. Part two is a multichannel medium resolution visible and near infrared spectrometer imager with tailored wavelength bands for the region 0.4 μ to 1.1μ) high resolution imager. Part two is a multichannel medium reolution visible and near infrared spectrometer imager with tailored wavelength bands for the region 0.4 μ to 2.7μ . Part three is a thermal mapper in the band, and part four is an ultraviolet and Fraunhofer line discriminator imager.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

A coordinated instrument of this type would operate as a Shuttle payload such as the ATL concept. The coastal zone resource imager would permit the rapid acquisition of information concerning variations in temperature of ocean masses near shore areas, the variation of shoreline geology, chlorophyll, and sedimentation and the effects and extent of chemical and thermal pollution.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Coastal Zone Resource Imager

7. TECHNOLOGY OPTIONS:

Technology options would include the desired, all solid state imager detector head, a hybrid system partly solid state and partly vacuum tube, solid state linear arrays or scanning mirror. Optical technology would be single or multiple channel lens or mirrors.

8. TECHNICAL PROBLEMS:

The basic concept of linear array pushbroom scanners has been demonstrated, but the extension of this technology to multiple detector material technology in one package would require utilization of back-up technology options.

9. POTENTIAL ALTERNATIVES:

A bore-sighted combination of some already developed might be feasible though optimization for coastal zone measurement would be difficult.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

MOCS

Reconofax

FLD

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Coastal Zone Resource Imager — PAGE 3 OF 3

12. TECHNOLOCY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Develop Remote Turbidity Monitoring Instrumentation — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Environment (Marine)

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop fast, remote methods of measuring seawater turbidity for oceanographic studies and satellite interpretations.

4. CURRENT STATE OF ART: A second generation optical backscatter turbidity system is being assembled with field tests scheduled for the summer (1975). HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

A transceiver consisting of a laser source and a telescope/photomultiplier detector is being used to study backscatter by a natural body of water. The incident laser beam is linearly polarized whereas the backscattered light is somewhat depolarized. This depolarization is attributable to multiple scattering by the suspended material in the water. Thus as the water becomes more turbid, the degree of depolarization increases.

The instrument being evaluated uses a 10 milliwatt CW argon-ion laser, an 8" telescope collector, and a polarization analyzer. It is designed to operate from an altitude of 100 meters and to measure beam attenuation (turbidity) over a range of 1 M^{-1} to 10 M^{-1}.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) NASA-NOAA satellite interpretation will be aided by a capability to measure turbidity, by simultaneous aircraft underflights. The LaRC ALOPE Program for Remotely Sensing Chlorophyll requires simultaneous turbidity measurement for calibration.

(b) In general the capability for measuring turbidity from aircraft should benefit geologists and oceanographers who now do the work from shipboard. The system being developed is simple and inexpensive and will be usable by non-experts with limited funds.

TO BE CARRIED TO LEVEL 6

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Develop Remote Turbidity Monitoring Instrumentation

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

The main problem in this technique is to establish a calibration curve for depolarization vs. turbidity. Field tests in various bodies of water will have to be performed to determine if a universal curve is possible, or whether several curves for various water types are necessary. The relationship between beam and diffuse attenuation coefficients must also be determined.

9. POTENTIAL ALTERNATIVES:

Quantitative Sediment Determinations using Multi-Spectral Data. Johnson/NASA LRC
Laser - Tyndall Scattering Techniques. Hirschberg and Bland University of Miami/
KSC RTOP 177-70-91
Short Pulse Laser Time Delay Techniques. J. Shannon/NADC
Additional Depolarization Studies (Lab) - Mayo/Texas A & M
- Granatstein/Bell Labs

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 506-18-12 is presently funding this work.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Develop Remote Turbidity Monitoring Instrumentation PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1 Component Tasks																			
2 Array Fabrication																			
3 Array Ground Task																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Develop Remote Monitoring Techniques for Ocean Salinity PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Environment (Marine)

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop fast, remote methods of measuring salinity over large bodies of water for oceanographic studies and satellite interpretation.

4. CURRENT STATE OF ART: A laser optical backscatter method has been shown to be successful in the lab. A prototype field system has been constructed and is being tested in a lab tank.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

A pulsed Nd:YAG laser and a double monochromator system are being developed to measure the backscattered Raman return from the sulfate ion (SO_4). Since SO_4 is in constant proportion to the other salts in the sea, it can be used as a measure of the salinity. The Raman water return is used as an internal standard.

Depth penetration decreases exponintially as turbidity increases, therefore penetration can vary from 40 ft. in coastal waters to as little as 1 to 2 ft. in highly turbid environments. Depth resolution is approx. 1.5 m and surface resolution may be about 1 M^2.

The expected precision is 10 to 15%, however an uncertainty of 20 to 25% would still yield useful information on large fresh water inputs into extuarines from storms and hurricanes.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

NASA-NOAA satellite interpretation require a knowledge of these quantities at many location around the globe.

It is expected that this system will be useful in dynamic estuarine environments where large changes in salinity over short periods of time can occur due to fresh water runoff, tides, and intermitent phenomenon such as storms and hurricanes. (These short term salinity variations are difficult to monitor using shipborne *in situ* equipment).

TO BE CARRIED TO LEVEL 6

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Develop Remote Monitoring Techniques for Ocean Salinity

7. **TECHNOLOGY OPTIONS:**

Older, conductivity analyses are regularly used by oceanographers, but are too slow for comprehensive comparisons with satellite data.

The only other remote technique now being developed is wave which is limited by surface resolution and depth penetration. The μ wave, however, does offer all weather capability.

8. **TECHNICAL PROBLEMS:**

A strong, spectrally broad fluorescence from unknown constituents in the water can limit salinity measurement. This background level must be measured under a variety of field conditions before the utility of this technique can be assessed.

9. **POTENTIAL ALTERNATIVES:**

The μ wave system is another remote measurement technique being developed for salinity, but does not penetrate to any appreciable depth.

Laser-Raman Scattering Technique also by Hirschberg and Bland. University of Miami/KSC KSC RTOP 177-70-91

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

RTOP 506-18-12 is presently funding this study.

EXPECTED UNPERTURBED LEVEL 6

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Development of reliable high power pulsed lasers.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Develop Remote Monitoring Techniques for Ocean Salinity

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Component Tasks																			
2. Array Fabrication																			
3. Array Ground Task																			
4. Array Space Checkout																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																TOTAL
TECHNOLOGY NEED DATE																
NUMBER OF LAUNCHES																

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Multi-Spectral Imaging System Studies for Planetary and Terrestrial Experiments

2. TECHNOLOGY CATEGORY: Improved multi-spectral imaging system design for scientific instruments.

3. OBJECTIVE/ADVANCEMENT REQUIRED: System studies for low-weight optics, low-power electronics, radiation-hardened electronics, and broad spectral optical systems to optimize a multi-spectral imaging system for planetary and terrestrial applications.

4. CURRENT STATE OF ART: Telescopes designed for remote sensing on unmanned spacecraft have thermal coatings and radiation-resistant glass types that several restrict the spectral range.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Multi-spectral imaging systems have extended the desired operating range from near UV to near IR (.25 to 8μ). Present optical systems flying on planetary and Earth orbiting missions do not have this wide spectral transmission throughput.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Improved scientific instrument design for light-weight and low-power subsystems. The applications also require large spectral range for optics.

b. All reflective optical system design trade-offs can possibly improve the present optical designs for multi-spectral imaging instruments.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Multi-spectral imaging System Studie. for Planetary and Terrestrial Experiments **PAGE 2 OF 2**

7. **TECHNOLOGY OPTIONS:**

An alternative to broad spectral optics would be to have multiple telescopes to cover the desired spectral range. This would not be cost-effective in the long run.

8. **TECHNICAL PROBLEMS:**

Focal plane will be significantly different throughout the spectral range.

9. **POTENTIAL ALTERNATIVES:**

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

EXPECTED UNPERTURBED LEVEL __

11. **RELATED TECHNOLOGY R'.QUIREMENTS:**

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Real-Time, On-Board Data Processing and Analysis Using Microprocessor for Specialized Multi-Spectral Imaging Applications both for terrestrial and Planetary Investigations. PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: On*Board Digital Image Processing

3. OBJECTIVE/ADVANCEMENT REQUIRED: Near real-time processing of multi-spectral imaging data for single ratios and/or differences or spectral channels for data turnaround analysis and short-time scale applications for both planetary and Earth applications.

4. CURRENT STATE OF ART: Reliable microprocessing on single chips, have add times as fast as -used, which allow the possibility of on-board digital image processing for high data rare multi-spectral imaging systems.

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

An on-board data processing system using microprocessors for special application such as comparison of rock reflectance spctral signatures for indicators of possible subsurface mineralization of economic value, or oil slick detection.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Experience with ERTS and Skylab EREP has shown that their multi-purpose scanner system fall short of yielding optimum results for specific tasks by the very nature of their generalized design. In particular, the spectral bands are often too broad or misplaced. For particular applications, experience has shown that 90% of the data returned is not directly applicable and exorbitant amounts of expensive time on large computers are required to extract the desired data to complete the analysis. Performing near real-time image processing calculations on-board and producing a completely analyzed picture product which highlights the alteration zones would be possible.

b. An on-board processing system should be developed to sufficient maturity to allow experimental demonstration on-board Shuttle for Earth applications and instrument design modifications for future planetary missions.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Real-Time, On-Board Data Processing and Analysis Using Microprocessor for Specialized Multi-spectral Imaging Applications Both for Terrestrial and Planetary Investigations. PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

The on-board processing has technology options to:

1. Develop faster microprocessor.

2. Look at parallel processing by use of multiple processors.

3. Trade-off with specialized analog/or digital logic for specific processing.

8. TECHNICAL PROBLEMS:

Use in Jovian Orbital Mission will require radiation hardening.

Faster processing may require more on-board data storage to match bandwidth of dark side.

9. POTENTIAL ALTERNATIVES:

Continue use of large computers on ground with usual ground data handling problems.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP #645-30-08 "Specialized Multi-Spectral Imaging and Analysis System"

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Real-Time, On-Board Data Processing and Analysis Using Microprocessor for Specialized Multi-Spectral Imaging Applications both for Terrestrial and Planetary Investigations PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

Paper presented at Symposium on Charge-Coupled Device Technology for Scientific Imaging Applications, 6 March 1975 at JPL, entitled: "A Specialized CCD Imaging and Analysis System for Earth Resources Application Problems."

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Multi-Spectral Earth Resources Facsimile Scanner — PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: Sensors and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide low-cost, multi-spectral, radiometrically calibratable images for earth resources in-situ measurement.

4. CURRENT STATE OF ART: All current multi-spectral images of earth resources are from A/C or S/C platforms or utilize nonimaging spectrometers or radiometers or film.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The facsimile imager consists of a multi-spectral scanning radiometer, whose output may be a standard image or radiometrically accurate spectral data array. The Multi-Spectral Earth Resources Facsimile Scanner would be similar in performance to the Facsimile Cameras on the Viking Mars Mission, but would be tailored for operation remotely on earth. The cameras would contain spectral channels that match chlorophyl reflectance, Fraunhofer line, forest fire detections, or any other visible or near infrared wavelength or band depending on the application. Modification in-situ would be simple process and would make such systems applicable to various Earth Resources Experiments from each instrument.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The MERFS would be the only system which could produce radiometrically accurate imagery data in one instrument with multi-spectral capability. The data rates which facsimile cameras use are compatible with many inexpensive terrestrial data rates. Facsimile cameras are low power and low weight, making them ideal for remote sensing both inactive experiments and practical applications such as forest health and fire detection. The low-cost of a developed system on a unit-to-unit basis plus their adaptability to a particular application would make them accessible to many users such as universities and other elements of the private sector.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): MERFS PAGE 2 OF 2

7. TECHNOLOGY OPTIONS:

Many technology options are available for MERFS systems for adapting them to particular tasks. These range from low power operation, simple systems to many channel automated versions utilizing microprocessors. Since all relevant technology exists, each MERFS could readily be tailored to a particular user need.

8. TECHNICAL PROBLEMS:

Since basic technology and implementation have been proved, no technical problems precluding operation are known.

9. POTENTIAL ALTERNATIVES:

There exists the possibility of utilizing CCD array systems with a multi-spectral capability, but these will never approach the flexibility of individual sensor heads and scanning capability of the MERFS.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

An earth resources camera of limited capability is currently under development.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

None

SECTION D: MICROWAVE SYSTEMS SENSING PAYLOADS

D-1 ADVANCED MICROWAVE RADIOMETER SYSTEMS

Application

This is an earth oriented microwave radiometer system which measures important oceanographic and meteorological characteristics that are covered under the Outlook for Space objectives: Water Availability (012), Large Scale Weather (021), Global Marine Weather (026), Local Weather and Severe Storms (031), and Stratospheric Changes and Effects (024). The oceanographic measurements that would be made include sea surface temperature, roughness (ocean wave structure), fractional foam coverage, and inferred wind speed. These key parameters are needed to increase man's understanding of the ocean/atmosphere interface and its influence on world weather and climate, hurricane and severe storm development, surface currents and areas of upwelling and its relation to marine biological productivity, and also to identify and forecast dangerous sea state conditions for ship re-routing. The primary meteorological measurements to be made are humidity profiles, cloud liquid-water content, vertical temperature, moisture and rain profiles, cloud top temperatures, and the vertical distribution of atmospheric trace constituents such as ozone. These latter measurements would also have important application to the previously cited needs associated with weather and heat balance of the earth. In addition, they would provide the important vertical profile data needed to develop and test three dimensional forecasting models of global weather and storms. These latter data would also provide a means for monitoring storm surges, tracks, and identification of regions where clear air turbulence may be encountered.

Payload Description

The payload consists of a group of six microwave radiometers which have center frequencies located at approximately 2.0, 6.0, 22.0, 60, 118, and 183 GHz.

These radiometer systems can be subdivided into nadir viewing (2.0, 6.0, 22.0, and 60 GHz) and limb scanning (60,118, and 183 GHz) radiometer instruments. The 2 and 6 GHz nadir viewing instruments are swept (or stepped) frequency wide bandwidth radiometer systems that are optimized for detection of radiometric signatures (polarization, viewing angle, and frequency) associated with sea surface temperature, roughness, foam coverage, and wind speed. These surface characteristics are all inferred from a radiometric measurement of surface brightness temperature determined at discrete microwave frequencies within a narrow bandwidth. Since all of these sea surface parameters affect the measured brightness temperature, measurements must be made over a range of frequencies in order to decouple this interaction. The 2-6 GHz frequency band was selected to maximize differences in the effects of these sea surface parameters on the brightness temperature-microwave frequency function so that decoupling can be accurately performed. The third nadir viewing radiometer is functionally the same as the first two but is sensitive to the 22 GHz water vapor band. The sweep frequency capability of this radiometer is used to measure both absolute attenuation and width of the water vapor line so that tropospheric water vapor profiles can be determined. In addition, this radiometer may be useful for rain rate measurement. The 60 GHz radiometer or Microwave Temperature Sounder (MTS) which can be used in either the radio viewing or limb scanning mode consists of twelve channels within the 60 GHz resonance region of molecular oxygen. It can be used to determine atmospheric temperature profiles from the brightness temperature distribution over the twelve microwave channels. The last two limb scanning radiometers are sensitive to upper atmospheric molecular oxygen temperature (118 GHz) and water vapor (183 GHz) and operate on the same principles previously described. Finally, it appears technically feasible to modify the MTS instrument to allow measurement of trace atmospheric constituents such as

CO (115 GHz), O_3 (183 GHz), and N_2O.

The essential technology developments and feasibility demonstrations of the instruments needed for this payload should be completed in time for a 1983 launch as indicated in the attached technology requirements documents. This schedule is such that it will directly benefit the following Outlook for Space Systems:

System #	Title	Launch Date
2007	Long Wavelength Passive Microwave System	1986
2011	Weather Survey System I-Development	1984
2027	Sea Survey System-Development	1985
2022	Stratospheric Ozone Monitoring Systems-Development	1985

Technology Advancement Required

The technology advancements required for this payload and associated readiness dates are radiometer components (1982), deployable reflector antennas (1982), and electronically scanned phased array antennas (1984). Technical details of the radiometer components are covered in the Appendix which follows. The antenna technology is covered in Section E.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Radiometer Components for Microwave and Millimeter Wave Remote Sensing PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Environment

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of wide band, low loss, stable front end components; low noise receivers; and optimum standardized electronics beginning at the IF stage of microwave/millimeter wave radiometer.

4. CURRENT STATE OF ART: A swept frequency, octave bandwidth radiometer operating in the 4-8 GHz range is currently under development. With the exception (cont on page 4) HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Conceptually, the microwave radiometer is no more than a simple RF receiver that measures thermal radiation collected by an antenna over a band of frequencies. However, for the data to be of value to the user, care must be exercised in the design and fabrication of the instrument. For example, if one wished to remotely detect a $1^{o}K$ change in ocean temperature, the instrument must be designed to resolve a difference in power level of only 0.013 dB. If accurate absolute measurements are to be achieved, extreme care must be taken to minimize the effects of component losses, thermal instability, and gain instability. These problems were solved at S-band during the development phase of a precision, narrow-band radiometer sponsored under the AAFE program.

For wide band operation, the key developmental elements in the front end of the radiometer are (1) the Dicke switch that provides modulation by alternately switching between the antenna and an internal reference noise source; (2) the RF amplifier; and (3) the mixer that down-converts to IF for subsequent amplification and detection.

R/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The electromagnetic spectrum spanning wavelengths between 25 cm and 0.1 cm have great potential for routine remote sensing of the earth, ocean, and the atmosphere. At the long wavelength, the atmosphere is virtually transparent; hence, the earth and the ocean can be viewed, independent of cloud cover and rain. The long wavelengths also tend to penetrate imperfect conductors of electricity, allowing unique measurements such as (1) "seeing" through some vegetation to obtain soil characteristics, and (2) obtaining water temperature averaged over a few centimeters of depth.

As the wavelength decreases, the radiometer becomes a remote sensor of the atmosphere and the earth surface under clear weather conditions. Atmospheric properties such as temperature and density can be inferred by measuring the radiation from water vapor and oxygen resonant lines. The highly dispersive (frequency dependent) nature of rain suggests that multi-wavelength measurements will provide a profiling capability.

These are but a few of the remote sensing applications of microwave radiometry. The fact that different phenomena are accentuated over the 250:1 wavelength range strongly points to a need for multi-wavelength measurements.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Advanced Radiometer Components for Microwave and Millimeter Wave Remote Sensing

7. TECHNOLOGY OPTIONS:

For some applications, the number of independent radiometric measurements can be reduced by utilizing active systems. For example, heavy weather cells can be profiled by comparing rain scatter as a function of time from a three-frequency short pulse weather radar.

Synthetic aperture radars can also provide images of terrain/ocean roughness characteristics where resolution of a few tens of meters is required.

Many phenomena, however, cannot be resolved with active systems, because radiometers are inherently more sensitive instruments.

8. TECHNICAL PROBLEMS:

1. Advances in fabrication technology is required for constructing wide band Dicke switches at the short wavelength.
2. Development of staggered-tuned parametric amplifiers is required at all wavelengths to obtain low-noise, wide band operation.
3. Development of pump sources for parametric amplifiers is required at the shorter wavelengths.
4. Development is required for impedance matching of wide band mixers at the shorter wavelengths.

9. POTENTIAL ALTERNATIVES:

The alternate approach is to construct separate radiometers for each observational wavelength. The advantages of this approach are (1) much less component development will be required, and (2) the receivers, being independent, do not require a time-share mode and can therefore view the scene for a longer period. The disadvantages are (1) more volume and power are required as the number of channels are expanded; (2) separate instrument biases may compound the error in both absolute and relative radiometric measurements; and (3) no ultra-wideband mode is available for rapid-scan radiometric imaging.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

A 4-8 GHz radiometer is being fabricated under RTOP 175-20-30, and an 18-26 GHz instrument is being planned. This RTOP, however, does not cover major component development to push the state of art at the higher frequencies. Experiment definition studies have also been done under the RTOP 750-01-12.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

Large aperture, scannable, wide band antennas.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Radiometer Components for Microwave and Millimeter Wave Remote Sensing PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Breadboard 4-8 GHz Rad	X	X																	
2. Breadboard 18-26 GHz		X	X																
3. Develop Low Freq. Staggered Tunnel Para.		X	X																
4. Develop Wide Band, Low Noise Comps.			X	X	X														
5. Breadb. Adv. Wide B. Rad					X	X													
6. Aircraft Tests		X	X	X		X	X												
APPLICATION																			
1. Design (Ph. C) Mod 1			X	X	X														
Mod 2						X	X	X											
2. Devl/Fab (Ph. D) Mod 1					X	X													
Mod 2								X	X										
3. Operations Mod 1							X	X	X										
Mod 2										X	X	X							
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. "Development of a Satellite Microwave Radiometer to Sense the Surface Temperature of the World Oceans," by G. M. Hidy, et al., NASA CR-1960, Feb. 1972.

2. "An S-Band Radiometer Design with High Absolute Precision," by W. N. Hardy, K. W. Gray, and A. W. Love; IEEE Trans. Microwave Theory and Techniques; Vol. MTT-22, pp. 382-390, April, 1974.

*3. "Studies in Microwave Radiometric Sensing of the Ocean," Final Report, Contract NAS1-10691, Rockwell International.

*Includes conceptual design for a swept frequency radiometer.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Radiometer Components for Microwave and Millimeter Wave Remote Sensing

4. CURRENT STATE OF ART: (cont'd.)

of the antenna, all the front end components perform satisfactorily over the bandwidth.

Present wide band receiver technology is such that 600°K is the lowest noise temperature that can be achieved. The noise temperature, sub-bandwidth and integration time impact upon the measurement resolution of brightness temperature.

D. ADVANCED RADAR/SCATTEROMETER SYSTEMS

1. ADVANCED IMAGING RADAR

Application

The Imaging Radar, an active microwave sensor has the capability to fill one or more roles in earth and ocean observation activities. It can serve as a complementary sensor providing an extension of the spectral description of the phenomena, or as a supplementary sensor providing an extension of observation coverage of the phenomena. It serves as a unique sensor providing information which is unobtainable by other sensors. It has all weather, day, and night capability. It can be used for the following observations and assessments: lake ice measurements and navigation, oil spill detection and measurement, land use, soil moisture, soil type, petroleum and mineral exploration and geographic applications, snowfield mappling, disaster assessment and relief (floods), water resources, agriculture, forestry, range, crop identification, land use (urban, regulatory and cartographic applications), pollution monitoring, iceberg charting/ sea ice/polar mapping/navigation/ship monitoring, and wind and wave measurement. Imaging radar is also expected to find application in personnel search and rescue missions rising passive (reflector) targets deployed by vehicle in emergency situations.

Payload Description

The proposed payload consists of a synthetic aperture radar (SAR), a device in which the time-doppler record of a radar signal is appropriately processed to obtain spatial resolution well within the diffraction limit of the transmitter/ receiver antenna. The range coordinate of the image is developed by transmitting a short pulse and recording the time history of the reflected signal, with the resolution being directly proportional to the transmitted compressed pulse width.

The azimuth coordinate of the image is achieved by processing the signal through a filter matched to the known doppler history of a scatterer as it passes through the along-track beamwidth of the antenna. The resolution in azimuth is inversely proportional to the time scatterer appears in the antenna beam. The response to a given frequency depends on the characteristics of the target. This sensor system could be ready for Shuttle Orbiter operations by 1985.

Technology Advancement Required

Technology advances are needed:

1. To prevent voltage breakdown of high power transmitters.

2. In the development of onboard solid state megabit data processors.

3. In the development of a solid state device to obtain pulse compression approaching one nanosecond.

4. In the development of large erectable multi-beam antennas. (see Section F).

Progress should be made in these areas starting now if the advanced imaging radar is to be flown in the 1985 time frame.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Imaging Radar System for Remote Sensing PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Environment

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of high power transmitters high data rate on-board image processors, and multiple (or time share) systems to develop large swathwidth imagery.

4. CURRENT STATE OF ART: Within NASA aircraft imaging radars utilizing optical recorders, achieve a resolution of 20 meters and a swath-width of 16 km. (cont on page 4) HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The synthetic aperture radar (SAR) is a clever technique, conceived by Carl Wiley, in which the time-doppler record of a radar signal is appropriately processed to obtain spatial resolution well within the diffraction limit of the transmit/receiver antenna. The range coordinate of the image is developed by transmitting a short pulse and recording the time history of the reflected signal, with the resolution being directly proportional to the transmitted compressed pulse width. The azimuth coordinate of the image is achieved by processing the signal through a filter matched to the known doppler history of a scatterer as it passed through the along-track beam-width of the antenna. The resolution in azimuth is inversely proportional to the time the scatterer appears in the antenna beam.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The LANDSAT spacecraft experience has shown that the user of satellite remote sensing data is interested in high resolution, multi-spectral images of a large swath of real estate. The imaging radar has the potential of providing all of this capability plus the additional features of penetrating clouds and of obtaining data during the night. This extended capability should attract more wide-spread user interest in satellite remote sensing data.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Advanced Imaging Radar System for Remote Sensing

7. TECHNOLOGY OPTIONS:

The user of remote sensing data is simultaneously pushing for finer spatial resolution and greater cross-track swath width. For a given transmitter power level, these are incompatible constraints for the imaging radar, i.e., fine resolution can be achieved only at the expense of reduced swath width. The possible options to overcome this difficulty are:

(1) Development of high power (perhaps megawatt) transmitters.

(2) Development of a parallel (or time share) transmitting system which will feed several antennae with contiguous beams to provide extended swath width.

(3) Development of a two-mode system, whereby the first mode yields a coarse image with large swath width, and the second mode provides a "zoom" capability for narrow field-of-view, fine imagery.

(Cont'd. on p. 4)

8. TECHNICAL PROBLEMS:

1. Advances in technology needed to prevent voltage breakdown of high power transmitters.

2. Advances are required in the development of onboard solid state megabit data processors.

(Cont'd. on p. 4)

9. POTENTIAL ALTERNATIVES:

The potential alternative is to utilize real aperture techniques to develop resolution in azimuth and/or range. This, however, requires an aperture of dimension approaching 10 km. This technology will probably not be available until the end of the century.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Development of key components for an imaging radar has been pursued under 160, 161, 645, and 638 RTOP's; however, the funding has been seriously cut back. CCD technology is currently being funded under 638 (AAFE) to develop analog, solid state matched filters.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Charge-coupled devices (CCDs), erectible multibeam antennas.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Imaging Radar System for Remote Sensing — PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Adv. Component Dev.																			
3. Fab. Breadboard																			
4. Fab. S/C Prototype																			
5. A/C Test of Prototype																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. The theory of the SAR is outlined in Chap. 23 of "Radar Handbook," by M. I. Skolnik, ed., McGraw-Hill, 1970.

2. Justification for the imaging radar for earth and ocean physics applications will appear in the forthcoming proceedings of the NASA Active Microwave Workshop held in Houston during the summer of '74.

3. A summary of the technology required to obtain a spacecraft imaging radar prior to 1980 is discussed in an AAFE proposal entitled "Coherent Imaging Radar" by W. E. Brown, Jr., dated May 15, 1973.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ______

1. **TECHNOLOGY REQUIREMENT (TITLE):** Advanced Imaging Radar System for Remote Sensing

4. CURRENT STATE OF ART: (cont'd.)

The SeaSat A imaging radar will achieve 25-50 meter resolution and a swath width of 20 km. Solid state data processing will be used on SeaSat. The state of the art within DOD is not known.

7. TECHNOLOGY OPTIONS: (cont'd.)

(4) Explore the possibility of using ambiguous PRF to improve the overall signal-to-noise ratio.

8. TECHNICAL PROBLEMS: (cont'd.)

3. Advances are required in the development of a solid state device to obtain pulse compression approaching 1 nanosecond.
4. SAB techniques cannot be used as geosynchronous altitudes, since relative motion between the earth and the satellite is required to construct the synthetic aperture.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Onboard Data Pre-Processing/Management Using CCD Technology — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: ______

3. OBJECTIVE/ADVANCEMENT REQUIRED: Multispectral/radar imaging gross data characterization and dynamic vehicle operational status determination. Adjustable algorithm CCD processors required.

4. CURRENT STATE OF ART: Possibility will be demonstrated September, 1975. Level 4 for adjustable devices - Level 6 for fixed tap devices.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

CCD fixed tap weight devices performing particular computations have demonstrated higher processing rates than large computers through the large amount of parallel processing and the wide dynamic range of sampled analog information under manipulation. This many orders of magnitude improvement in size, weight and power makes onboard processing a reasonable solution to some of the data transmission problems. Device designs and tradeoffs must be made in the direction of decreasing this advantage to allow variable algorithms, and this work is currently underway.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) SeaSat A imaging radar requires 70 Mb/sec data link for transmission of radar return data and slow image processing on general purpose computer driving AAFE-CCD SAR IPM.

(b) All payloads may benefit from this new technology, some to a lesser degree.

(c) Makes imaging radar feasible; adjustable algorithm devices will allow multiple missions from same hardware configuration, changing only sensors, algorithms, and desired outputs.

(d) Level of technology maturity should start with Shuttle mission then be carried to Venus Probe/VOIR.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Onboard Data Pre-Processing/Management Using CCD Technology — PAGE 2 OF 3

7. **TECHNOLOGY OPTIONS:**

The main viable alternative to this technology is a special purpose digital computer which would consume many orders of magnitude more size, weight, power to perform a similar function.

8. **TECHNICAL PROBLEMS:**

Potential problems are in the maximum resolutions achievable, and in the maximum and minimum serial data rates. Other potential problems are in MOS and surface state instabilities exhibited in a radiation environment.

9. **POTENTIAL ALTERNATIVES:**

Increased data rate communications links and large onboard memories or world-wide data receiving network.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

502-52-03 (?) - Electron Devices to Demonstrate Feasibility of Such Devices

AAFE Exp. SAR-IPM at JPL to demonstrate imaging from radar return data in an aircraft experiment using a uniquely designed fixed tap weight device. Semiconductor manufacturers see no ground use competitive advantage in this area, therefore, expected unperturbed Level 4.

EXPECTED UNPERTURBED LEVEL __

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Algorithm determinations from users.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Onboard Data Pre-Processing/Management Using CCD Technology

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
Systems Studies																			
Design Trade																			
Design																			
Fabrication																			
Test Levels:																			
3																			
4																			
5																			
6																			
7																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

2. LONG WAVELENGTH (PENETRATING) RADAR

Application

The long wavelength radar system provides the ability to do near subsurface sensing from spacecraft or aircraft. Detection of soil moisture can be done. Near subsurface anomolies (minerals, water, man-made) are detectable.

Payload Description

The long wavelength radar (transmitter, receiver, and variable angle narrow beam antenna) transmitting at an appropriate wavelength and sufficient power to penetrate the surface will acquire data from the backscatter return, to do near subsurface mapping and soil moisture analysis.

Technology Advancement Required

The long wavelength radar presents two major problems. The data processing is extremely complex, additionally so because of earth surface returns. A large antenna is required for the narrow beam long wavelength system.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Long Wavelength (Penetrating) Radar System Development

PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Remote Sensing

3. OBJECTIVE/ADVANCEMENT REQUIRED: Ability to perform subsurface sensing using radar techniques from aircraft or spacecraft.

4. CURRENT STATE OF ART: Laboratory and field experiments have been performed to prove feasibility. The Joint Soil Moisture Experiment (JSME) has shown that moisture is detectable at depths of 10 Cm.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Microwave systems have been developed to obtain the back-scattered return from land and water surfaces. Due to changes in dielectric constant penetration of the surface could detect (1) buried items in construction sites (pipes, etc.), (2) hidden items in other areas, and (3) near surface water, mineral deposits, etc. A microwave system will be developed which utilizes a transmitter, receiver, and a variable angle narrow beam antenna. The system would transmit adequate power at an appropriate wavelength to penetrate the surface and provide data or a map of the back-scatter return.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Radar as a remote sensor has great potential for sensing surface phenomena.

(b) This potential would be greatly improved by extending the ability of radar systems to sense below the surface to a depth of several meters.

(c) Study, analyses and field testing of such a system will provide the technology improvements (primarily in the area of data analysis) to make a prototype system feasible.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Long Wavelength (Penetrating) Radar System Development

7. **TECHNOLOGY OPTIONS:**

Use magnatometers in aircraft or orbital spacecraft to sense anomalies in the earth's magnetic field which may be relaxed to subsurface phenomena.

8. **TECHNICAL PROBLEMS:**

   1. Surface reflections from the earth.
   2. Size of antennas needed for system.
   3. Complexity of data analysis.

9. **POTENTIAL ALTERNATIVES:**

Perform such measurements on ground using antennas tightly coupled to the earth's surface.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

RTOP 177-51-84, Joint Soil Moisture Experiment (JSME); currently investigating depth of penetration of lower microwave and upper UHF frequencies into the earth's surface.

EXPECTED UNPERTURBED LEVEL 5

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Improved modeling techniques for electro-magnetic back-scatter phenomena.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Long Wavelength (Penetrating) Radar System Development

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis		—																	
2. Field T sts			—																
3. Field Data Analysis				—															
4. A/C System Dev.				—															
5. A/C Flight Test					—														
6. A/C Data Eval.						—													
APPLICATION																			
1. Design (Ph. C)		—	—	—	—	—													
2. Devl/Fab (Ph. D)						—	—	—											
3. Operations									—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE									▲									
NUMBER OF LAUNCHES									2	2	2	2	2	2	2	2	2	18

14. REFERENCES:

(1) Feasibility Study of Electromagnetic Subsurface Profiling
R. M. Morey and W. S. Harrington, Jr.
EPA-R2-72-082, Oct 1972

(2) The Use of Complex Dielectric Constant as a Diagnostic Tool for the Remote Sensing of Terrestrial Materials
R. S. Vickers and G. C. Rose, Contract No. F19628-70-C-0035,
Colorado State University, Aug (1971)

(3) Active Microwave Measurement of Soil Water Content
F. T. Ulaby, J. Cihlar and P. K. Moore, Remote Sensing of Environment, 3, 185-203 (1974)

(4) Remote Sensing of the Earth by Microwaves
K. Tomiyasu, Proc. IEEE 62, No. 1, 86-92, January (1974)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** ______

1. TECHNOLOGY REQUIREMENT (TITLE): Long Wavelength (Penetrating) Radar System Development **PAGE** 4 **OF** 4

(5) Application of Dielectric Constant Measurements to Radar Imagery Interpretation
M. Leonard Bryan and R. W. Larson, Report, Environmental Research Institute of Michigan, NASA Contract-21783, (1974)

(6) The Response of Terrestrial Surface at Microwave Frequencies
W. H. Peake and T. L. Oliver, Technical Report No. AFAL-TR-70-301
Ohio State University May 1971

3. CONDUCTIVITY MEASURING SYSTEM

Application

This system will be used to determine the conductivities of materials at the earth's surface and subsurface. The data thus acquired will support other earth observations.

Payload Description

The payload is a microwave system of two transmitters, receivers, antennas, phase measuring detection circuits, and a phase difference circuit. Conductivity of surface and subsurface materials, a function of the dielectric constant of the material, can be determined by measuring the difference in phase of the reflection coefficients of two signals of different frequencies at the surface interfaces.

Technology Advancement Required

The conductivity measuring system requires the development of stable phase measuring circuits, and data management systems. The effect of antennas on phase measurement must be removed from the systems. Surface interface models require definition.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Microwave Conductivity Measurement System Development PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Remote Sensing

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of a microwave measure- for remote sensing to support earth observation application studies.

4. CURRENT STATE OF ART: Studies have been conducted to define the measurement technique, but hardware has not been developed to test the concept.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Conductivity of surface and subsurface materials is a function of the dielectric constant of the material. Conductivity can be determined by measuring the difference in phase of the reflection coefficiencts of two signals at different frequencies at the surface interfaces. A microwave system will be developed which utilizes two transmitters, receivers, antennas, phase measuring detection and difference circuits. The system will transmit identical signals at two frequencies and detect the changes in phase of the returned signals.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Radar as a remote sensor has a great potential for sensing surface and subsurface phenomena.

(b) This potential would be greatly improved by developing techniques to sense surface and subsurface interface interfaces.

(c) Study, analysis and field testing of such a system will provide the technology improvements (primarily in the area of data analysis) to make a prototype system feasible.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT | NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Microwave Conductivity Measurement System Development

7. TECHNOLOGY OPTIONS:

Continue to use presently available microwave sensors only to make measurements in support of earth observation application studies.

8. TECHNICAL PROBLEMS:

1. Developing stable phase measuring circuits.
2. Developing stable difference measuring circuits.
3. Developing data handling and analysis hardware.
4. Defining surface interface models.
5. Design of antennas to not affect the phase measurements.

9. POTENTIAL ALTERNATIVES:

Use probes in the surface or subsurface layers to make the conductivity measurements.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Inhouse definition studies at the Applied Research Laboratories at the University of Texas at Austin.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of flight worthy highly stable phase and difference measuring circuits.

LEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Microwave Conductivity Measurement System Development PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Electronic Dev.																			
3. Field Tests & Analys.																			
4. A/C System Dev.																			
5. A/C Tests & Analys.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE								4										
NUMBER OF LAUNCHES									2	2	2	2	2	2	2	2	2	18

14. REFERENCES:

(1) Handbook of Electromagnetic Propagation and Conducting Media, M. B. Kraichman, Pages 2-1 thru 2-6, 1970
U. S. Government Printing Office

(2) Electromagnetic Theory, J. A. Stratton, Pages 490 thru 500 and 505 thru 516
McGraw-Hill, 1941

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

D-3 ADVANCED SATELLITE METEOROLOGICAL RADAR

Application

Feasible uses of a satellite meteorological radar system include the following:

a. Sampling of rainfall data in tropical storms with sufficient horizontal resolution (5-6 km or less) to resolve the rain bands. Vertical resolution of 1-2 km is required.

b. Gathering global rainfall statistics including otherwise inaccessible regions of the earth.

c. Refinement of global water cycle information and study of the atmospheric heat budget related thereto.

d. Testing rainfall predictions of present and near-term future numerical atmospheric models.

e. Rate of latent heat release due to water condensation as an input to numerical atmospheric circulation models that may be developed in the future.

f. Gap filling data as an adjunct to ground-based weather radars and as an aid in local severe storm prediction.

g. Use of surface backscatter information to study soil moisture, crop vigor and height, and boundaries, and characteristics of sea and polar ice.

h. Possible use of mean dopple shifts of raindrops as indicators of horizontal winds at various altitudes in rainstorms.

Payload Description

An advanced meteorological radar system, incorporating technology gained from a vigorous research program carried out aboard aircraft, is to be flown on the Shuttle Orbiter. It will be cost and operationally constrained, but will have the capability of demonstrating the utility of and exercising the designs required for an advanced operational system beyond 1985.

Technology Advancement Required

Basic meteorological and radar data interpretation research must be done. It is necessary to develop data interpretation schemes and algorithms capable of coping with the constraints of the measurement problem and at the same time being capable of on-board implementation. Developments are required leading to large Butler-matrix phased array antennas. High power spaceborne transmitters and low noise receivers are needed. An extremely large capacity on-board data handling capability is required.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Meteorological Radar PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Weather and Climate

3. OBJECTIVE/ADVANCEMENT REQUIRED: High power microwave tubes, lower noise receivers, very large simultaneous multiple beam phased-array antenna system, and large capacity on-board data handling and processing equipment.

4. CURRENT STATE OF ART: 2 kw peak power radar transmitter operated on Skylab with duty cycle of 3×10^{-5}. Aircraft meteorological radars in existence and under development do not address required antenna or data handling (cont'd.)

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Some current proposals for single frequency Shuttle meteorological radars for 1981 and beyond require two phased-array antennas, each 5 × 30 meters, connected to a single transmitter but to 160 separate receiver channels. Each channel would further be doppler filtered to achieve synthetic sharpening of beams. Such schemes are necessary as opposed to scanning a single beam to achieve large number of pulse samples per footprint and wide swath coverage simultaneously. Each synthetically sharpened receiver beam (∿800 total) would need 40 or more range bins, resulting in overall data rate greater than 1 Gbit/sec. Significant on-board data compression is thus required. Transmitter powers of 15 kw peak or greater and 8 db or less noise figure are required. To encompass the cloud top height measurement, these capabilities must extend up to about 94 Ghz.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Active Microwave Workshop of 1974 emphasized feasibility and need for satellite meteorological radars. Global rainfall rate and/or cloud height would be of decided benefit to meteorological community. Passive microwave sensors cannot resolve these height profiles; particularly difficult is the quantitative determination of rainfall rates, because of the erratic height variability associated with it. Although benefits are fairly definite, the relationship between the obtained data and the meteorological situation requires research, as does the entire sensing and data interpretation problem.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Advanced Meteorological Radar **PAGE 2 OF 4**

7. TECHNOLOGY OPTIONS:

Achieving the user requirements regarding resolution coverage, and accuracy in global rainfall measurements leaves little room for options in the overall sense. In specific areas such as the means of achieving synthetic sharpening of the resolution cell through doppler techniques, there can remain choices such as between doppler analog filtering or computational measuring of the time-dom in signal. The latter would require more extensive on-board data processing capability. Another possibility would be the construction of the three-dimensional radar reflectivity map of precipitation by a form of microwave holography using a large number of effective antennas.

8. TECHNICAL PROBLEMS:

Development of data interpretation schemes and algorithms capable of coping with the constraints of the measurement problem and at the same time being capable of on-board implementation.
Large Butler matrix phased array antennas.
High power spaceborne transmitters and low noise receivers.
Extremely large capacity on-board data handling capability.

9. POTENTIAL ALTERNATIVES:

Laser radar would be a potential alternative to mm radar waves for cloud top height determination.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

AAFE meteorological aircraft radar program will provide b information related to data interpretation and actual requirements and constraints for satellite demonstration and operational radars.
Antenna development transmitter tube and receiver improvements, and on-board data handling capabilities which may be developed in connection with planned Imaging Radars and Radiometers will have direct impact on the met. radar.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

CCD devices for data processors.
Large antenna steering and deployment devices.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Meteorological Radar — PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Aircraft met. radar program (AAFE)																			
2. Shuttle Demonstration																			
3. Operational Satellite met. radar																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** ______

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Meteorological Radar **PAGE** 4 **OF** 4

5. DESCRIPTION OF TECHNOLOGY: (cont'd. from p. 1)

and processing required for satellite case. Other radars and radiometers do currently incorporate required synthetic aperture techniques. Present on-board data handling capability is primitive compared to ultimate needs.

SECTION E: TECHNOLOGY DEVELOPMENT/EVALUATION PAYLOADS

E-1 LARGE DEPLOYABLE MICROWAVE ANTENNAS

1. ADVANCED ELECTRONICALLY SCANNED PHASED ARRAY ANTENNA

Application

The payload antenna will provide the accuracy necessary for microwave radiometric sensing of the environment.

Payload Description

The payload antenna is a phased array of known ohmic losses which are thermally stabilized, and it is cryogenically cooled for oceanographic applications.

Technology Advancement Required

The main problem presented by the antenna is the requirement of thermal stability. An antenna with the proper thermal characteristics and a cooling system need to be matched to provide thermal stability over long time periods--one day on aircraft and months on a spacecraft. The antenna must maintain its operating integrity at 100 degrees K and on up to room temperature. It is not known whether the ferrite phase shifters used for frequencies above X-band will work at the low temperatures.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Electronically Scanned Phased Array Antennas for Remote Sensing PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Environment

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of an integrated package of critical phased array antenna components that can give satisfactory electrical performance for microwave radiometer remote sensing measurements.

4. CURRENT STATE OF ART: The design of electronically scanned phased arrays is a well developed art. The key components, however, are thermally stabilized to operate at near room temperature. HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

The construction of phased arrays is a well developed technique. Key components such as phase shifters, power dividers, and hybrids are commercially available. The problem with the phased array is that the ohmic losses of the components are detrimental to the accuracy of remote sensing measurements, particularly microwave radiometer measurements. If phased arrays are to be useful for precision radiometric applications, the losses must be accurately known and thermally stabilized. For oceanographic applications, cryogenic cooling of the components would be highly desirable.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:
Phased arrays offer two desirable advantages over other types of antennas. First of all, the array is only a few inches deep and is therefore relatively easy to install on spacecraft and a variety of aircraft. To illustrate the packaging difficulties of other antennas, a low loss horn, 8 feet tall, is being installed in a C-54 for L-band radiometer measurements. A phased array of the same aperture size would be less than a foot tall. The second advantage of the phased array is that scanning is done electronically. This means that no torque compensation is required for spacecraft; and there is no need for large radomes for aircraft measurements.

The losses in the phased array pose very serious problems in radiometry. As an example, the "brightness temperature" of the ocean (effective grey-body radiation) is approximately 100°K. The accuracy with which the measurement must be made is 0.3°K. Now, the lossy components in the antenna are also thermal radiators, whose emissivity is specified by the numeric loss number. If the components were held at room temperature, the measurement would suffer from the following deficiencies:

1. A 1 dB less would add a 40°K bias on the measurement.
2. The temperature of each component must be known to within 1°K to meet the specified measurement accuracy. (cont on pg. 4) TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Advanced Electronically Scanned Phased Array Antennas for Remote Sensing

7. **TECHNOLOGY OPTIONS:**

With regard to hybrids and power dividers, the technology options are stripline vs. air-filled coaxial transmission lines. Stripline offers miniaturization because of the high dielectric constant, but are inherently lossy. Air-filled lines present low loss, but miniaturization and fabrication are problem areas. As far as phase shifters are concerned, diodes present low loss, but the efficiency decreases with increasing frequency. Ferrites are lossy, but allow operation at high frequency and reduce line length for good phase control.

8. **TECHNICAL PROBLEMS:**

1. Mechanical design of an integrated compact package is required, such that thermal instability of the individual components can be maintained.
2. It is necessary to design and quality parts to operate at 100°K, and preferably over a range up to room temperature.

(cont'd. on p. 4)

9. **POTENTIAL ALTERNATIVES:**

Horn and reflector antennas exhibit very low loss and broad bandwidth. These antennas should definitely be used in projects where mechanical scanning and installation pose no problems.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

A combination precision S- and L-band dual radiometer system is currently being flight-tested under RTOP to measure accurately temperature and salinity in coastal areas. This is an ideal candidate system to incorporate a cryogenic phased array.

EXPECTED UNPERTURBED LEVEL ___

11. **RELATED TECHNOLOGY REQUIREMENTS:**

The ohmic loss of any imperfect conductor generally decreases with temperature. A cryogenic phased array will therefore increase the efficiency of an antenna; and, therefore, allow reduction in the transmitted power required. For radar, the dividend is doubled since the system must both transmit and receive through a common antenna.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Electronically Scanned Phased Array Antennas for Remote Sensing

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1 Tech. Tradeoff/Analysis																			
2 Des. of Components/Cry.																			
3 Component Fab/Integ.																			
4 Fab./Test of A/C Ant.																			
5 Fab./Test of S/C Comp.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

The one reference which encompasses the need for precision radiometry and an antenna tradeoff study is given in:

"Development of a Satellite Microwave Radiometer to Sense the Surface Temperature of the World Oceans," by G. M. Hidy, et al. NASA CR-1960 February, 1972.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Electronically Scanned Phased Array Antennas for Remote Sensing PAGE 4 OF 4

6. RATIONALE AND ANALYSIS: (cont'd.)

   3) The total loss must be known to within 0.006 dB to meet the accuracy requirements.

If the components could be cryogenically cooled to closely match the brightness temperature of the ocean, the bias would be 1^oK instead of 40^oK and the loss must be known only to 0.27 dB instead of 0.006 dB. The component temperature must still be known to within a degree, but careful packaging techniques can solve this problem.

The brightness temperature of other targets, such as terrain and ice, are generally higher than water; therefore, a higher stable component temperature is required to minimize the effect of losses.

8. TECHNICAL PROBLEMS: (cont'd.)

3. Development of a compact cryogenic unit and heat exchanger to maintain constant temperature for one day in an aircraft environment, and months in a space environment.
4. Ferrite phase shifters are presently used at frequencies above X-band. The performance of ferrites is temperature sensitive; and it is not known if operation at low temperatures is feasible.

2. OPEN FEED ACTIVE MICROWAVE ANTENNA

Application

The antenna is proposed as a payload for the Shuttle Orbiter so that its performance characteristics may be ascertained in the space environment. It is presently in the early design stages as a part of the Earth Resources and Oceanographic Imaging Radar (RTOP 645-30-07). It is designed to test the antenna for arcing, corona or breakdown before committing to the radar system implementation. The tests will also validate the design of structure and mechanisms.

Payload Description

The payload is primarily a large (Approximately 3m X 12m) light weight antenna with transmitter with variable power, duty cycle and PRF and appropriate feed systems. Open wave guide and microstrip designs are being considered for the antenna. The tests will provide limits of performance with regard to arcing, corona or breakdown in the antenna and power feed systems. Performance of the structural and mechanisms design will provide secondary information.

Technology Advancement Required

The potential problems of breakdown, corona and shorts for this flight weight antenna design must be overcome. The antenna design should be proven in the space environment early so that the total imaging radar system is ready for flight in the 1980's.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Test and Evaluation of Open Feed Active Microwave Antennas in Space PAGE 1 OF ___

2. TECHNOLOGY CATEGORY: Microwave Hardware Development

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development and test of light weight antennas in the space environment to present operation problems such as corona.

4. CURRENT STATE OF ART: Lightweight antennas are being developed but none have been tested at the possible power levels expected for future instrumentation.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Proposed designs of the Earth Resources Shuttle Imaging Radar antenna are using an open antenna concept. Due to the potential power required arcing, corona or breakdown caused by shorting may occur in the antenna and power feed systems. To prove the concept and reduce the risk for the radar operations, a test antenna should be flown on an early shuttle flight. The test article would include an antenna, a transmitter with a variable power, duty cycle and PRF and the appropriate feed systems. The test would also provide evaluation of the antenna for use in other microwave projects (solar power).

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Very large antennas are needed to obtain appropriate gain and resolution for microwave remote sensing.

(b) To reduce weight of the antenna open waveguide and microstrip designs are being investigated.

(c) Antennas of this type have been flown on aircraft in much smaller versions.

(d) Without such a test the exact breakdown point of the antenna would not be known and the maximum utilization of the antenna could never be used.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Test and Evaluation of Open Feed Active Microwave Antennas in Space PAGE 2 OF

7. TECHNOLOGY OPTIONS:

The antenna could be flown without any testing redizing the risks involved or the antenna could be tested in a ground chamber if one is large enough. However, the exact characteristics of space around a satellite or the Shuttle will not be known and the full potential of the antenna never realized.

8. TECHNICAL PROBLEMS:

1. Breakdown limits of this antenna design.
2. Corona of this antenna design.
3. Potential for shorts in the antenna design.

9. POTENTIAL ALTERNATIVES:

Use pressurized feed and antenna systems.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 645-30-07 is presently defining an imaging radar to support earth resources and oceanographic applications from the Shuttle.

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

Improved antenna design for light weight antenna for microwave applications.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Test and Evaluation of Open Feed Active Microwave Antennas in Space

PAGE 3 OF ___

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1 Analysis																			
2 Development																			
3 Test and Evaluation																			
4 Redesign																			
5 Test and Evaluation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES					2	2	2										6

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. ______
1. TECHNOLOGY REQUIREMENT (TITLE): ________________	PAGE ___ OF ___

3. DEPLOYABLE MICROWAVE REFLECTOR ANTENNA

Application

The payload antenna will demonstrate the technology developments leading to a low-loss, efficient large aperture scanning antenna for microwave remote sensors.

Payload Description

The antenna will be a demonstration article used to prove the technology required to provide large erectable-relector and phased-array antennas for microwave remote sensing of the earth's surface.

Technology Advancement Required

The technology must be developed in the following areas:

1. Wide-band feed clusters for reflector antennas.
2. Determination of antenna pattern distortion associated with a scanning feed.
3. Methods required for preserving the surface tolerance of very large reflectors.
4. Low-loss and/or loss-stable phased-array components. Cryogenic cooling of phase shifters, power dividers, etc. may be required.
5. Solutions of structural and mechanism problems related to these large antennas.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Antennas for Remote Sensing (Deployable Reflector Antenna)

2. TECHNOLOGY CATEGORY: Environment

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of low-loss, efficient large aperture scanning antennas for microwave remote sensors.

4. CURRENT STATE OF ART: Space erectable, parabolic, antenna reflectors up to 10 meters in diameter are well within the present state of the art at S-band (cont'd. on p. 4)

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

In the years beyond 1980, there will be a need for large erectable-reflector and phased-array antennas for microwave remote sensing of the earth's surface. These antennas will require (a) a scanning capability, (b) low side lobe levels, (c) very low or accurately known ohmic losses, (d) polarization purity, and for some applications (e) wide bandwidths. The ATS program demonstrated that large parabolic reflectors can be erected in space. As indicated previously, however, parabolic reflectors are not suitable for remote sensing for the reasons listed. Therefore, other reflector types must be investigated to meet the general requirements listed. For reference purposes, the advantages and disadvantages of a few reflector types are listed below.

(cont'd. on p. 5)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The Seasat-A radiometer and scatterometer systems offer a spatial resolution of approximately 100 km. This resolution is adequate for the study of ocean dynamics, but much too coarse for other applications. For example, radiometric temperature measurements over a cell not exceeding 10-20 km is required for the data to be of value to the fishing industry. Near coastal zone, earth resources, and topside weather radar measurements require even finer spatial resolution. Hence, a more widespread variety of users can be satisfied by increasing the spatial resolution.

(b) Users are generally uninterested in remote sensing measurements unless a cross-track swath of data is collected.

(c) The user is demanding more accurate data. In the area of microwave radiometry, the antenna ohmic loss and side lobes are the major contributors of accuracy degradation.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Antennas for Remote Sensing (Deployable Reflector Antenna)

7. **TECHNOLOGY OPTIONS:**

The alternative means to achieve higher spatial resolution with real apertures is to operate at a higher electromagnetic frequency. This, however, destroys the near all-weather capability that microwaves provide for earth observations.

8. **TECHNICAL PROBLEMS:**

(a) Development of wide-band feed clusters required for reflector antennas.
(b) Amount of antenna pattern distortion associated with a scanning feed is unknown.
(c) Development of methods required for preserving the surface tolerance of very large reflectors.
(d) Development of low-loss and/or loss-stable phased-array components. Cryogenic cooling of phase shifters, power dividers, etc., may be required.

9. **POTENTIAL ALTERNATIVES:**

In the area of microwave radiometry, there is no obvious method of achieving a high resolution swath without resorting to large antennas.
For active, nonimaging systems, it is possible to reduce the antenna size in one dimension and use the doppler effect to discriminate range cells along the satellite track. Swath width can be developed by orienting the fan beam at an angle to the satellite velocity vector.

(cont'd. on p. 6)

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

The new Advanced Applications Flight Experiment (AAFE) contract on large reflector antennas and the RTOPs at JPL (645-25-02, 506-20-22, 506-17-15) are somewhat related to the described requirements.
The state of the art (of remote sensing antennas) at the need data if NASA expends no special effort in this area will probably be as follows:

(cont'd. on p. 6)

EXPECTED UNPERTURBED LEVEL 3

11. **RELATED TECHNOLOGY REQUIREMENTS:**

With regard to reflector antennas for remote sensing, the feed scanning area must be investigated - in particular the mechanical design required if movement of the feed is necessary. The deployment mechanism, actuating system, etc., must be developed for offset feed reflectors.
In the area of phased-array antennas, work must be conducted to determine thermal control designs for cryogenic phase distribution networks. Tradeoff studies will be needed to determine the best approach for variable phase shifters. Then the array design approach could be formulated.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Remote Sensing Antennas (Deployable Reflector Antenna) PAGE 3 OF 6

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Remote Sensing Design Requirements (Analysis)																			
2. Survey of Reflector Design																			
3. Reflector/Feed Design																			
4. Fabrication of Engineer Model																			
5. Ground Tests (Thermal, Electrical)																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. "Deployable Reflector Design for Ku-Band Operation." NASA CR-132526, Harris Corp., September 1974.
2. "Large Deployable Antenna Shuttle Experiment." Research and Technology Operating Plan 645-25-02, Jet Propulsion Laboratory, July 19, 1974.
3. "Large Deployable Antenna Shuttle Experiment." JPL Interoffice Memo 3392-75-42, February 24, 1975.
4. "Dual-S and Ku-Band Tracking Feed for a TDRS Reflector Antenna - Tradeoff Study." N75-10312, NASA CR-139122, Martin Marietta Aerospace Corp.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

4. CURRENT STATE OF THE ART (cont'd.):

operating frequencies. X-band frequencies have also been used with reflectors of this size in space applications. The most recent application is the 40-foot diameter parabolic reflector currently deployed and operating on the ATS-F spacecraft. The state of the art for reflectors of this size has been improved through the Advanced Applications Flight Experiment (AAFE) Contract NASA-11444 (NASA CR-132526). Included in this contract was the demonstration of the lightweight, double-mesh concept through the fabrication of a 12.5-feet diameter reflector (weight 23 lbs.) for Ku-band operation. This design concept will probably be used on the Tracking and Data Relay Satellite (TDRS). The AAFE Program is extending the large reflector studies under a contract that will investigate design possibilities for reflectors up to 100 meters in diameter. In a parallel effort, the Jet Propulsion Laboratory is proposing a large Deployable Antenna Shuttle Experiment (LDASE). The recommended reflector size for this experiment is 100 feet in diameter with a surface quality of 0.050 inch (vms). The recommended size and surface quality for LDASE was based on mechanical consideration only, since it was considered inappropriate to base the size of the antenna on user requirements. (Ref. JPL Interoffice Memo 3392-75-42.) Since a parabolic reflector would be selected for a 100-foot diameter design. However, there are several disadvantages in using parabolic reflectors for remote sensing applications. A few are listed below:

a. Some energy is reflected back into the feed.

b. The feed partially blocks the radiating aperture (this causes a loss in gain and an increase in side lobes).

c. The receiver front end has to be mounted at the focal point to avoid a long waveguide run to the back of the dish. This is not convenient.

d. Beam scan by feed movement is limited to a few beamwidths before there is excessive gain loss.

e. Spillover is highest in rearward direction.

Therefore, the current state of the art as well as present plans for the future appear to be oriented more toward parabolic reflectors for communications and others, rather than reflectors for remote sensing applications.

5. DESCRIPTION OF TECHNOLOGY (cont'd.):

A. Spherical Reflector

(1) Advantages

(a) This type of structure allows excellent wide angle scanning even as much as ±15° by a simple rotation of the feed about the center of the sphere. (More conservatively, one could expect a scan capability of 25 beamwidths with _ 1 dB loss).

(2) Disadvantages

(a) Some radiated energy is reflected back into the feed.
(b) The feed blocks the radiating aperture.
(c) Receiver has to be mounted at the focal point.

B. Offset Fed Reflector

(1) Advantages

(a) There is no feed blockage and usually no support blockage, too.
(b) No radiated energy is reflected back into the feed.
(c) Spillover is directed neither forward or backward.

(2) Disadvantages

(a) Beam scanning by feed movement is not widely documented.
(b) In one plane, the beam tends to be asymmetrical.
(c) Design principles and procedures are not widely known.

C. Offset Fed Cassegrain

(1) Advantages

(a) There is no blockage due to supports or subreflectors.
(b) Spillover is not rearward.
(c) The offset subreflector allows for some better aperture utilization than the single reflector offset fed antenna due to spillover.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Antennas for Remote Sensing (Deployable Reflector Antenna) PAGE 6 OF 6

5. DESCRIPTION OF TECHNOLOGY (cont'd.):

(2) Disadvantages

(a) In existing configurations, the axes of rotation are not orthogonal. This may require some angular coordinate conversion in the positioning mechanism.

(b) Design not known.

Therefore, from this brief reflector comparison, it can be seen that reflectors other than parabolic may be amenable to remote sensing applications. The problems associated with, for example, the spherical or offset feed parabolic section should be addressed. These particular antennas are of interest for remote sensing because they exhibit wide angle scanning and no spillover characteristics, respectively. Mechanical inertia will more than likely preclude scanning the reflector; hence, the problems associated with fast beam steering by motion of the feed should be addressed.

The phased array if of interest because scanning and multiple beam operation can be achieved by electronic means. This, therefore, eliminates the need for torque compensation on the spacecraft. However, the packaging erection and the relatively large ohmic losses present technology problems which must be addressed before the arrays are suitable for remote sensing applications.

9. POTENTIAL ALTERNATIVES (cont'd.):

In principle, the resolution offered by the synthetic aperture radar increases with decreasing size of the physical aperture. In practice, however, reasonably large antennas are needed for gain to boost the signal-to-noise ratio.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT (cont'd.):

(a) A capability for deploying large parabolic (approx. 100 feet in diameter) reflectors will be available but no capability for reflectors more conducive to remote sensing applications.

(b) Dual frequency, tracking feeds will be available but none with scanning capability suitable for remote sensing.

(c) A capability will exist for packaging large reflector antennas and this could be applied to remote sensing designs.

E-2 IMAGING RADAR CALIBRATION SYSTEM

Application

The system would enhance the correlation of imaging radar data taken at different sites or on different missions. It will allow quantitative back-scatter measurements to be made while in orbit.

Payload Description

The payload will consist of a functional imaging radar system which allows a testing of the calibration subsystem. To provide full or absolute calibration of an imaging radar, several techniques must be applied simultaneously to relate the power transmitted to the power returned. First, a stabilized source is required to provide a sample of the transmitter power with distinct step amplitude levels to the receiver and associated processor and data system. Secondly, a thorough knowledge of the antenna is needed, such as illumination coverage, power transfer through the antenna, and changes of the antenna because of environmental conditions. Thirdly, an understanding of the effects of the atmosphere between the antenna and target is needed to understand loss of signal and phase rotation. Fourth, an array of extended and controlled ground targets, with ground truth, is required to determine the total effect of the target signal to the output of the radar system. The stable source will be used to monitor and correct for any changes in the radar electronics, such as change in output power, system sensitivity, stability, etc. Knowledge of antenna characteristics will allow for corrections of data due to antenna ground coverage, gain variations, transfer losses, etc. Knowledge of the atmospheric effects will allow for corrections of the data due to losses or phase rotations through the signal transfer medium. The ground range will provide a standard reference to which all other target data can be absolutely related or correlated.

Technology Advancement Required

The calibration system depends on improvements in several areas. A long term stable electronic reference signal is required. Complete knowledge of the antenna performance must be available. Improved modeling of the earth's atmosphere must be available. Ground truth arrays observable by the orbiting radar are necessary as are variables associated with the earth's surface reflectivity.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Imaging Radar Calibration System Development PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Remote Sensing

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increase the ability of imaging radar systems to make quantitative back-scatter measurements from orbit.

4. CURRENT STATE OF ART: An electronic system has been tested in an aircraft, but no end to end system calibration system involving extended ground targets has been developed. HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

Radar images are used for several Earth Resources Survey applications. Present systems provide a map of the imaged area at different frequencies, polarizations, etc., depending on the capability of the system. An objectional characteristic of these systems is that the data cannot be completely correlated from mission to mission or site to site because the data cannot be compared to a common reference. A calibration system will be developed which utilizes stabilized microwave components and references that would provide calibration of the data during data gathering. The calibration system would be an electronics and field application of new techniques.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Amplitude calibration of back-scatter will be required if imaging radar systems are to be used to make quantitative remote sensing measurements.

(b) A combination of electronic references and a controlled field array can provide this measure of calibration.

(c) Without such a system, only relative measurements could be made.

(d) This technology should be carried to an experimental demonstration on an early shuttle flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Imaging Radar Calibration System Development

7. TECHNOLOGY OPTIONS:

Back-scatter measurements may also be performed with a scatterometer. These instruments may be calibrated to an accuracy of ± 8 db. However, scatterometers can only take data fore and aft of the flight line and do not provide an image. Using a scatterometer to gather the same data, an imaging radar would require repetitive flying of parallel flight lines.

8. TECHNICAL PROBLEMS:

1. Development of a stable electronic reference signal.
2. Realistic modeling of the earth's atmosphere and factoring the model into the calibration system.
3. Variables associated with the earth's surface reflectivity.
4. Knowledge of the antenna system.

9. POTENTIAL ALTERNATIVES:

Perform relative measurements using large extended targets such as water, sand and grassfields as standards to compare to roughen targets.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 645-30-07. Earth Resources Shuttle Imaging Radar (ERSIR) could be expanded in scope to also investigate calibration.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

Improved imaging radar techniques for aircraft applications.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Imaging Radar Calibration System Development

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Electronic Development																			
3. Range Development																			
4. A/C Evaluation																			
5. Implement on ERSIR																			
6. Shuttle Flight																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES									2	2	2	2	2	2	2	2	2	18

14. REFERENCES:

(1) "The Response of Terrestrial Surface at Microwave Frequencies" W. H. Peake and T. L. Oliver, Technical Report No. AFAL-TR-70-301, Ohio State University, May (1971)

(2) Moore, R. K., "Ground Echo" in Radar Handbook, Ch. 25, M. I. Skolnik, ed., New York: McGraw Hill, 1970

(3) "Amplitude Calibrated Techniques Applied to the Environmental Research Institute of Michigan's Airborne SAR System," R. W. Larson, F. Smith, R. J. Salmer and W. Zimmerman, ERIM, Proceedings of 19th Annual Tri-Service Radar Symposium

(4) "Specification and Testing of Airborne Imaging Radars". Study S-296 S. Fiarder Institute of Defense Analysis, Science and Technology Division, 12/67

(5) "Imaging Radars for Earth Resources" Technical Report LEC/HASD 6492-21-006, July, 1969. (Lenon Stafford)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

E-3 SUBMILLIMETER WAVELENGTH RECEIVERS

Applic ion

The submil! meter wavelength receivers have use in the following applications:

(1) Terrestrial Atmospheric Observations from the Shuttle Orbiter.

(2) Astronomical and Planetary Observations from the Shuttle Orbiter.

(3) Radiometric Sensors on Missions to Planets and Comets.

(4) High Data Rate, Secure Inter-Satellite-Spacecraft Communications.

Payload Descriptio

The system proposed is a submillimeter (to 1000 GHZ) low-noise coherent receiver combining microwave and optical techniques and its supporting subsystems. It can be used as a radiometer for remote observations of terrestrial atmospheric parameters which cannot be measured at the lower frequencies. One example is the measurement of ClO to 10^{-11} relative atmospheric abundance from observations at 980 GHZ. Observations of submillimeter spectral lines of planets and comets will provide basic scientific information and improved definition of payloads for planetory missions. The receivers will provide higher data rate communications than previously available. Because of atmospheric absorption, secure satellite and spacecraft communications are feasible. The capabilities of this kind of system are desirable in the early period of Shuttle Orbiter operational status.

Technology Advancement Required

The technical problems are:

(1) Efficient coupling of signal and local oscillator to non-linear device.

(2) Production of efficient non-linear devices for operation at 1000 GHZ.

(3) Production of local oscillator sources for 1000 GHZ.

Assuming an operational readiness requirement of mid-1980, development of the receivers should be embarked on now.

E-3

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Development of Submillimeter Wavelength Receivers

2. TECHNOLOGY CATEGORY: ____

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased operating frequency (to 1000 GHz) of low-noise coherent receivers through combination of microwave and optical techniques.

4. CURRENT STATE OF ART: Low-noise coherent receivers have been developed at frequencies up to ∿100 GHz, as typified by present ground-based radio astronomy instrumentation.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY Technological developments in four areas are required in order to produce low-noise coherent receivers operating up to 1000 GHz frequency. These areas, and recent advances which indicate the feasibility of obtaining such receivers, are:

1) Optical front end for receiver. An extremely high-efficiency optical receiver front end for operation at 115 GHz has been developed for the JPL Microwave Limb Sounder experiment for the Space Shuttle. Such techniques can be used to 1000 GHz and higher.

2) Coupling of signal and local oscillator to non-linear device. Quasi optical techniques, being developed by GISS and JPL, appear capable of operating to 1000 GHz.

3) Non-linear devices. Schottky-barrier diodes having non-circular dot geometry (now being developed by U. Va. under JPL contract for operation at 180 GHz) could be developed for low-noise operation to 1000 GHz. Josephson junction devices could also be used for these devices.

4) Local oscillator sources. Solid-state Gunn or Impatt oscillators operating above 100 GHz have been developed, as well as high-efficiency multipliers to 300 GHz. Higher harmonic multipliers could be developed to 1000 GHz.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS: Low-noise, coherent, submillimeter wavelength receivers will be of extreme importance to the space program in the 1980-2000 time frame for several applications listed below. The technology advancement should be carried to an experimental demonstration on an early Shuttle flight.

1) Terrestrial Atmospheric Observations from the Space Shuttle. The receivers will be used as radiometric sensors for remote observations of atmospheric parameters which cannot be measured at the frequencies. One example is the measurement of ClO to 10^{-11} relative atmospheric abundance from observations at 980 GHz. Measurement of ClO is particularly important for understanding the extent to which freon from aerosol cans will deplete Earth's ozone layer. Such measurements could influence national policy decisions. Many other important molecules can also be measured with such receivers.

2) Astronomical and Planetary Observations from the Space Shuttle. The receivers will be used for observations of planets, comets and interstellar molecules which cannot be observed from the ground. For example, observations at 180, 325, and 557 GHZ will tremendously improve knowledge of the known interstellar H_2O maser. Observations of submillimeter spectral lines of planets and comets will provide basic scientific information and improved definition of payloads for planetary missions.

3) Missions to Planets and Comets. The receivers will be used as radiometric sensors on missions to Venus, Jupiter, Saturn, and Uranus.

4) Spacecraft and Secure Satellite Communications. The receivers will provide higher data rate communications than previously available. Because of atmospheric absorption, secure satellite and aircraft communications are feasible.

TO BE CARRIED TO LEVEL 9

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Development of Submillimeter Wavelength Receivers — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

None.

8. TECHNICAL PROBLEMS:

1. Efficient coupling of signal and local oscillator to non-linear device.
2. Production of efficient non-linear devices for operation to 1000 GHz.
3. Production of local oscillator sources to 1000 GHz.

9. POTENTIAL ALTERNATIVES:

The technical problems mentioned above can be solved through a logical developmental program. Techniques for solving these problems are mentioned in 5 above.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 188-78-56, "Millimeter Wave and Far Infrared Detectors," has supplied some of the background work to develop efficient techniques for coupling signal and local oscillators to non-linear devices. Present programs will lead to development of receivers to 180 GHz only.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

No related technology is required for obtaining usable receivers. Development of low-noise intermediate frequency maser amplifiers and cryogenic coolers for use in space would improve the performance of the receiver.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Development of Submillimeter Wavelength Receivers

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Prototype 180 GHz Receiver.............																			
2. 360 GHz Receiver																			
3. 1000 GHz Receiver ...																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES						2	4	4	4	6	6	6	6	6	6	6	6	62

14. REFERENCES:

1. "A Quasi Optical Local Oscillator Injection System," by J. J. Gustincic, Proc. URSI National Meeting, Boulder, Colorado, October 1975.
2. "Varactor Frequency Doublers and Triplers for the 200 to 300 GHz Range," L. O. Cohen, et al., 1975 IEEE MIT Symposium, Palo Alto, California, 1975.
3. "Impatt Source for 184 GHz Phase-Locked Local Oscillator for Jet Propulsion Laboratory," proposal by Hughes Aircraft Co., April 1975.
4. "Cryogenic Cooling of Mixers for Millimeter and Centimeter Wavelengths," S. Weinreb & A. Karr, IEEE Jnl, Solid State Circuits SC-8, 58, 1973.
5. "Millimeter-Wavelength Radio Astronomy Techniques," A. A. Penzias & C. A. Burrus, Ann. Rev. Astrn. Astrophys., 51, 1973.
6. "Prospects for Microwave Limb Sounding of the Atmosphere," J. W. Waters, Opt. Soc. America Topical Meeting on Remote Sensing, 1975.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

E-4 EARTH VIEWING IR COMPONENT EVALUATION

Application

This payload consists of a number of advanced infrared components that have a variety of earth viewing and planetory applications. Specifically this payload supports the following Outlook for Space themes:

01 - Production and Management of Food and Forestry Resources

02 - Prediction and Protection of the Environment

03 - Protection of Life and Property

11 - The Evolution of the Solar System

Payload Description

This payload consists of a cluster of four infrared radiometers each with its own detector and detector cooling system. One of the radiometers will be equipped with a filter wheel or other filter exchange mechanism. It is envisioned that this payload would be used to demonstrate infrared components prior to their being committed to a particular spacecraft system. The radiometer cluster would have about a 500 meter ground resolution from Shuttle altitudes and would be used in an earth viewing mode. The resulting measurements have application in planetary thermal mapping, cloud cover monitoring, ice and snow field mapping, sea surface temperature mapping, land surface thermal mapping, and earth and planet cloud top temperatures. The advanced infrared detectors demonstrated in this payload would also have wide application in a variety of infrared spectrometers. A technology demonstration flight in about 1983 would enable the technology to be utilized on missions launched after 1985. Listed in the 1973 mission model are 11 planetary and cometary missions and 30 earth observation missions between 1985-1991 that could use this technology.

The pointing system employed would be capable of pointing to a particular area on the earth and complete a quick scan of the area or the Shuttle passes over.

Technology Advancement Required

A. COOLERS - It is envisioned that each of the four radiometers utilize a different cooler concept. At least two of these coolers should be cooling engines of the Vuilleumier or Sterling type. One of the coolers should be an advanced solid cryogen and one should be a liquid cryogen cooler. In the field of infrared coolers the main technology advancement required is that of long life. Although a seven or fourteen day Shuttle sortie mission will not yield a great deal of data toward the goal of a two (2) year cooler lifetime, it will enable the cooler to operate coupled to an IR detector in vacuum and a zero g field. Vibration problems associated with the cooling engines can be investigated and actual power consumption and cooler performance can be monitored. The solid and liquid cryogenic systems were included into the payload to encourage development of these cooling concepts. Although the cooling engines have received more attention in recent years because of their potential longer life, it is not entirely clear that with the relaxed payload weights in low earth orbit made po ssible by the Shuttle system that a rotating engine will be more cost effective, reliable, and longer life than a solid or liquid cooler.

B. DETECTORS - The desired trend in infrared detectors is to increase the dynamic and spectral range. If an advanced infrared detector can be developed with sufficient sensitivity range from about 3 to 15 micrometers, it will greatly increase the usefulness of a particular IR instrument while reducing its cost. The temperature sensitivity of most IR detectors is as much as 0.5% per degree Kelvin. If this sensitivity could be reduced it would greatly relax cryogenic cooler stability requirements.

C. FILTERS - The development of narrow band, high transmission filters would enable the development of associated low-cost spectrometers. Although a space flight of filter is not required for its development, its incorporation into this payload significantly increases the science yield of the mission. State-of-the-art filters could also be used.

D. POINTING SYSTEMS - The pointing system envisioned in this payload will not be completely described in this writeup but would have the capability to point to a given area and complete a rapid scan of that area while the Shuttle passes over the particular target.

Associated Mission Model

Payload Number	Name
PL-13	Mercury Orbiter
PL-20	Mariner/Saturn Orbiter
PL-22	Jupiter/Saturn Orbiter/Lander
PL-26	Asteroid Rendezvous
LUN-1	Lunar Orbiter
EO-3	Earth Observation Satellite
EO-4	Sync. Earth Observation Satellite
EO-7	Sync. Meteorological Satellite
EO-8	Earth Observation Sortie Mission

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Ultra Narrow Band Filter for Remote Sensing PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Design and develop Infrared bandpass filters of the Fabry Perot Interference type to advance the capability of IR spectroradiometers for the detection and measurement of line strengths in molecular spectra.

4. CURRENT STATE OF ART: Visible filters have been carried to level 6 (Fraunhofer Line Discriminator Program). IR filters are in the early design phase.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Ultra narrow band filter requirements for atmospheric absorption experiments:

Wavelength range: 5μ to 20μ (2000 cm^{-1} to 500 cm^{01})

Full width, half max. range: $3 \times 10^{-4}\mu$ to $1 \times 10^{-3}\mu$ (0.12 cm^{-1} tp 0.025 cm^{-1})

Transmission: 0.50

Optical ray cone angle: 2^{o}

Operating temp: $80^{o}K$

By tilting the filter, limited wavelength tuning can be accomplished to scan several spectral lines in the IR spectrum.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. Filters to be incorporated into a differential absorption spectroradiometer to measure atmospheric gas composition and pollutants.
2. Global coverage of the Earth environment from air-Sat or Shuttle.
3. Provides greater spectral specificity and detection capability over present broadband filters used in LRIR or proposed LACATE sensors.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Ultra Narrow Ba.'d Filter for Remote Sensing **PAGE 2 OF** 3

7. **TECHNOLOGY OPTIONS:**

IR Laser tuning techniques may accomplish same measurements in differential absorption spectrometry.

8. **TECHNICAL PROBLEMS:**

IR Material selections, design for specific wavelength filters, wavelength shifts with filter temperature change, integration of filter and detector into compatible sensing subsystem.

9. **POTENTIAL ALTERNATIVES:**

Useful as a blocking filter in laser tuning differential absorption spectrometry.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

None.

EXPECTED UNPERTURBED LEVEL ___

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Requires use with large diameter collecting optics (1 meter) and cooled detector filter subsystem.

DEFINITION OF TECHNOLOGY REQUIREMENT　　　　NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Ultra Narrow Band Filter for Remote Sensing　　　　PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Design																			
3. Fabrication																			
4. Ground Task																			
5. Space Checkout																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE							Δ											
NUMBER OF LAUNCHES																		

14. REFERENCES:

Ultra narrow band interference filter - AAFE Proposal Summer 1975

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Optimize detectivity, response time and operating temperature.

4. CURRENT STATE OF ART: In the 1-14 micrometers range, II-VI and III-V semiconductor detectors have detectivities above 10^{10} cm-Hz$^{\frac{1}{2}}$-watt^{-1} but require cooling to 80^{o}K. (See p. 4) HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

The III-V and II-VI semiconductor detectors are available in photoconductive devices or photovoltaic devices. From 1-5 micrometers, binary compounds will suffice. Above 5 micrometers, the peak response as a function of wavelength can be varied in a II-VI ternary compound (for example, $Hg_xCd_{1-x}Te$ and $Pb_x Sn_{1-x} Te$) by changing the ratios of the Group II constituents.

A pyroelectric detector consists of a slab of pyroelectric material having two opposite face areas coated with conductive layers to form a capacitor. A change in temperature generates a signal current proportional to the pyroelectric coefficient. To optimize the signal, a material should possess a low heat capacity, low dielectric constant, and large pyroelectric coefficient. Since the signal current is proportional to the rate-of-change of the temperature, this detector is more attractive than other types of uncooled thermal detectors for higher frequency applications.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

These devices are used for remote sensing in earth resources missions, environmental pollution monitoring, and thermal mapping.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Infrared Dectectors for Remote Sensing

7. TECHNOLOGY OPTIONS:

The detectivity of the II-VI ternary compounds can be increased to the point where it is practical to operate these devices at higher temperatures than $80^{o}K$. The detectivity of the pyroelectric can be increased to $\sim 10^{10}$ cm-$Hg^{\frac{1}{2}}$-watt^{-1}.

8. TECHNICAL PROBLEMS:

1. Control of homogeneity in III-V and II-VI materials restricts array construction.
2. Poor reproducibility of detector parameters in III-V and II-VI materials.
3. Relatively low operating temperature ($\sim 80^{o}K$) in the II-VI ternary materials.
4. Relatively low detectivity in pyroelectric detectors.

(cont'd. on p. 4)

9. POTENTIAL ALTERNATIVES:

If temperatures on the order of $35^{o}K$ can be achieved for the desired mission, it is suggested that doped silicon detectors be employed because of their higher detectivity in the wavelength range greater than 5 micrometers. In addition, the detector preamplifier can be directly incorporated with the device.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 506-18-21, "Electronic Devices and Components," contains elements bearing on this technology, such as an indium antimonide CCD sensor and pyroelectric detector materials investigations.

EXPECTED UNPERTURBED LEVEL 8

11. RELATED TECHNOLOGY REQUIREMENTS:

Advancement in preamplifier performance technology; improved material growth technology; small volume, low power cooling systems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM: 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91

TECHNOLOGY:

Pyroelectric Detectors:
1. Elec. Component Des.
2. Component Development
3. Array or CCD Hybrid Fabrication
4. Space Checkout

III-V & II-VI Compound Detectors:
1. Materials Growth
2. Detector Fabrication
3. Analysis
4. Ground Checkout
5. Space Checkout

4.

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. "Infrared Technology for Remote Sensing," Special Issue, Proceedings of the IEEE, 63, No. 1 (1975).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Detectors for Remote Sensing

4. CURRENT STATE OF ART: (cont'd.)

Over the wavelength range 1-20 micrometers, pyroelectric detectors have a relatively low detectivity ($D^* \approx 5 \times 10^8$ cm-Hg$^{\frac{1}{2}}$ -watt^{-1}) but require little or no cooling.

8. TECHNICAL PROBLEMS: (cont'd.)

5. Relatively long response times in pyroelectric detectors which restricts their practical operating frequency.

6. Pyroelectric detectors highly sensitive to vibrations.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Red Extended Pin Silicon Photodiodes   PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop pin silicon photodiodes that can operate at 1.0 μm without large sensitivity changes with temperature.

4. CURRENT STATE OF ART: Presently silicon photodiode responsibility is very temperature sensitive at 1 μm.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Silicon photodiodes temperature sensitivity at 1 μm is large - 0.5% per °C. This change would appear, for example, as a signal change with solar heating. One solution is to extend the peak spectral sensitivity toward 1 μm. This, however, may force a more undesirable mode, i.e., reverse bias.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) These diodes are needed in remote sensing of aerosols since 1 μm is an atmospheric "window" region with no interfering gaseous absorption.

(b) Could be used on SAM II/Nimbus-G, SAGE/AEM B, and future Shuttle missions.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Silicon Photodiode... PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

(a) Germanium might be applicable.

(b) Active temperature control.

8. TECHNICAL PROBLEMS:

Construction of such diodes.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 642-12-13 is developing the SAM II/Nimbus-G hardware.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

None.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Silicon Photodiode... PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis & Design																			
2. Breadboard & Test																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Optimization of Infrared Radiation Detection PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Infrared Detectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reduction of low temperature operational requirements for infrared detectors

4. CURRENT STATE OF ART: Low noise tri-metal detectors - operate at temperatures no higher than $90^{O}K$ as typified by S191 on Skylab.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

To generate usable signals in long wavelength infrared detectors, the detector must be cooled to temperatures near $77^{O}K$. Operation at higher temperatures is limited because of the presence of inherent thermal noise. Frequently, the cooling process introduces a significant amount of noise. The use of liquid nitrogen cooling is inconvenient, and can be hazardous to personnel. It is suggested that a low-noise, moderate temperature detector may be developed through a methodical computer aided research program in terms of general material, environmental, and impurity considerations such as band structure, transport properties, and temperature.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Relaxed temperature requirements for infrared detectors are required so that weight and power consumption required for cooling may be reduced and flexibility may be expanded.

(b) Low altitude and orbital earth observation remote sensing systems will benefit from this technology.

(c) Mechanical refrigerators of liquid nitrogen cooling devices severely limit the flexibility and the operating time of infrared detection systems.

(d) This technology advancement will be a new capability derived from present infrared detector technology.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Optimization of Infrared Radiation Detection PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

An alternative to moderate temperature detectors would be to find a suitable means of cooling detectors to low temperature by non-mechanical means such as by cryogenic pumping techniques. This type system would be closed cycle and free from the noise generated by a mechanical pump.

8. TECHNICAL PROBLEMS:

1. Processing or fabrication problems.
2. Environmental considerations.
3. Mathematical expression of a generalized detector.

9. POTENTIAL ALTERNATIVES:

Investigate detector characteristics as related to fundamental material properties separately as well as in combination.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL 2

11. RELATED TECHNOLOGY REQUIREMENTS:

Low-noise pre-amplifiers.

Design cryogenic refrigerators with less stringent cold temperature requirements.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Optimization of Infrared Radiation Detection

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Mathematical Model																			
3. Fabrication Techniques Developed																			
4. Fabrication																			
5. System Integration																			
6. Testing & Documentation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES								2	2	3	4							11

14. REFERENCES:

(1) Infrared System Engineering by Richard D. Hudson, Jr., 1969

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Radiative Refrigeration Design PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Infrared Detector Refrigeration

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased sensitivity of infrared systems used in orbital applications for remote sensing of environment.

4. CURRENT STATE OF ART: Several designs for passive systems have been used, but evaluations and design tasks have not been attempted for lack of opportunity.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The sensitivity of infrared detectors is dependent on the attainment and maintenance of very low temperatures - near liquid nitrogen. The practical approach to this requirement for long term missions is to utilize passive radiative refrigeration systems. The operation of these hinges on the temperature difference between outer space and the object requiring cooling. Several designs have been used in an attempt to accomplish the required results. These efforts have met with moderate success. A new system based on a comprehensive evaluation of current approaches concurrent with a design effort would provide increased infrared detection sensitivity.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Currently used infrared detectors require temperatures in the range of 80 degrees Kelvin.

(b) Development of this system would benefit satellite designs of the ERTS-c type. In some applications, the Themmatic Mapper would benefit.

(c) Present designs provide temperatures in the 195°K range with theoretical predictions down to about 100°K. Improvements would result in greater ground target thermal resolution, probably by an order of magnitude.

(d) This technology advancement should be carried to an experimental demonstration in an early Shuttle flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Radiative Refrigeration Design PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

The effectiveness of passive refrigeration devices relate to the ability of the system to radiate into outer space. This is a materials, as well as a geometry problem. It is proposed that a pallet of several designs be simultaneously evaluated in a modular/adjustment configuration permitting real-time interactive modifications.

8. TECHNICAL PROBLEMS:

1. Thermal path between infrared detector and refrigeration system.
2. Ability of system to radiate into outer space (Radiator Design).
3. Pointing of system into outer space.

9. POTENTIAL ALTERNATIVES:

Possibly using adsorptive pumping techniques using solar energy for power input in a conventional refrigeration cycle.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Current research by JSC for development of adsorption pumping techniques for use in cryogenic refrigeration purposes.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Infrared detector technology, low temperature technology, remote sensing technology.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Radiative Refrigeration Design — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Mechanical & Thermal Design																			
3. Fabrication																			
4. Test																			
5. Documentation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES						2	3	2	1									8

14. REFERENCES:

"Infrared System Engineering" by Richard D. Hudson, Jr. 1969

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Technology and Materials for Interference Filters and Anti-Reflection Coatings PAGE 1 OF ___

2. TECHNOLOGY CATEGORY: Remote Sensing of Stratosphere Gases

3. OBJECTIVE/ADVANCEMENT REQUIRED: More durable, stable, interference coatings for IR optical elements in the 1-20 μm spectral range. Must withstand prolonged operation at Cryogenic temperatures and/or in proximity with important trace constituents (HCl, SO_2, etc.)

4. CURRENT STATE OF ART: Multi-layer anti-reflection (MLAR) or filter coatings exist, but have not been space qualified for operation in gas-filters or at suitable cryogenic temperatures for required life times.

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Multi-layer AR and Filter Coatings have been used for several years in IR sensor systems. The system spectral response (particularly out-of-band) in operation has often not been that predicted based on the design and individual component measurements. The systems to-date have usually not been adequately evaluated after prolonged exposure to cryogenic temperatures or space and the long-term stability under such conditions. Nor have such coatings been used in proximity with gaseous constituents unless they were known to be inert. Present IR coating materials must be evaluated under realistic use conditions for stability over durations of six months to three years.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

- Multi-layer anti-reflectance coatings are needed in all electro-optical sensors.
- Background blocking filters are required in all narrow-band electro-optical sensors.
- Trace constituent measurements will require maximum sensitivity achievable and therefore require coatings used at cryogenic temperatures (30K to 150K).
- Trace constituent measurements will require maximum spectral discrimination thus requiring coating of elements in proximity with "active" gases.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT

NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Improved Limb Viewing IR Radiometer

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

- Multi-channel inflight calibration techniques which match calibration levels to flight data ranges and having required accuracy.
- Higher sensitivity detectors for the 5-20 m spectral range.
- Long-life detector coolers with reasonable weight and/or power requirements.
- Improved spectral filtering.
- Improved out-of-field energy rejection.

9. POTENTIAL ALTERNATIVES:

Develop multi-constituent sensors for simultaneous measurement of related parameters using spectroscopic, interferometric, or laser approaches for measurement in solar occultation mode.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 176-10-31 has a low level of funding to support some studies relating to improvements of existing AAFE-LACATE sensor design (active scanning, azimuth pointing filter radiometer).

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

- As discussed herein.
- Improved spacecraft attitude rate measurement subsystems for correction of data for spacecraft motion during data taking.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Limb Viewing IR Radiometer

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY A. Existing Design																			
1. Component SRT	x	x																	
2. Improved Design		x																	
3. EM Development																			
B. New Design Approaches																			
1. Analysis & Tradeoffs	x																		
2. Design		x	x																
3. EM Development				x	x														
APPLICATION																			
1. Preliminary Stratospheric survey-existing design							x	x											
2. Flight test new design								x											
3. Stratospheric Survey									x	x									
										x	x								

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			x			x												
NUMBER OF LAUNCHES							1	1	1									

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Stratospheric Research (Gases) PAGE 3 OF 4

2. TECHNOLOGY CATEGORY: Remote Sensing from Satellites

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased sensitivity detectors, very high resolution instrument techniques, advanced airborne detector cooling system technology.

4. CURRENT STATE OF ART: Present IR detectors provide a figure of merit (D^* in the 10^9–10^{11} range. Instrumentation for satellite global monitoring is capable of 0.1 cm^{-1} spectral resolution, (cont'd) HAS BEEN CARRIED TO LEVEL ____

5. DESCRIPTION OF TECHNOLOGY

The sensitivity needed to study the gases of importance in future stratospheric research will require a one to two order of magnitude improvement in detector D^*. Also, the spectral resolution capability for an operational monitoring instrument (in the infrared) will need to be increased by about one order of magnitude to 0.01 cm^{-1}. Long lifetime detector cooling systems are required (2-3 years) with operating temperature capability in the range of 30K or less. The most hopeful approach to meeting these cooling needs is the use of a closed cycle system such as the Vuilleumier (VM) cooler. A goal should be an operating power of no more than 60 watts.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Present systems for remote measurement of stratospheric parameters from satellites have been designed to measure the more obvious, less difficult trace gases (e.g., O_3, H_2O, CH_4, N_2O, NO_2, NO, HNO_3, and CO). However, as our knowledge of the stratosphere advances, there will be a need to measure some of the more subtle but very important stratospheric gases. Some of these gases which are involved in the ozone depletion problem include OH, HCl, HM, HBr, Cl, ClO, CP_x, Cl_y, ("Freons"), HO_2, Br_u, CH_3Br, CCl_4, and CH_3Cl. Others which are important from the standpoint of radiation balance and aerosol-can chemistry include SO_2 and NH_3. All of these gases have concentrations in the parts per trillion range and most of them have not been observed in the stratosphere primarily because of limitations on instrumental sensitivity and spectral resolution. It may be necessary to cool not only the detectors but also the instrument optics in order to achieve the desired sensitivity. Monitoring instruments for operational use are needed to measure long-term trends in these constituents.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Stratospheric Research (Gases) PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

None.

8. TECHNICAL PROBLEMS:

It may not be feasible in the near future to construct a long lifetime cooling system which would operate at the desired temperature and power levels, especially if optics must also be cooled.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Various programs are presently underway to measure stratospheric trace gases both in the limb emission and occultation modes. These include the Nimbus G SAMS and LIMS and the Atmospheric Explorer SAGE. In addition, improve LACATE and SAMS programs are in progress. These concepts could be extended and the efforts focused on achieving the desired technology advances.

(cont'd.)

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ____________________ PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** ______

1. **TECHNOLOGY REQUIREMENT (TITLE):** Stratospheric Research (Gases) **PAGE** 4 **OF** 4

4. CURRENT STATE OF ART: (cont'd.)

and cooling is achieved presently by use of solid cryogen technology (65K operation). Refrigerator systems are under development but present approaches create heavy power loads.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT: (cont'd.)

Also, various interferometer and spectrometer techniques have been used from balloons and aircraft. These approaches could be optimized for a specific gas or set of gases in designing a monitoring instrument. In the cooler area, various military and NASA programs are underway to advance the technology. These efforts will serve as base points in building future technology.

SECTION F: ASTRONOMY/PLANETARY PAYLOADS

F-1 EXTREME ULTRAVIOLET ASTRONOMY

Application

Astronomical observations in the extreme ultraviolet support at least 4 of the 12 Outlook for Space themes. The specific themes supported by this payload are:

08 The Nature of the Universe

09 The Origins and Fate of Matter

10 The Life Cycle of the Sun and Stars

11 The Evolution of the Solar System

Payload Description

The Extreme Ultraviolet Astronomy payload will consist of a collection of advanced extreme ultraviolet instrumentation which will include:

a. Extreme UV telescope with advanced optics of about 40 cm operative.

b. Multiple instrument magazine for the XUV telescope with at least 3 advanced extreme UV detectors one of which will be on imaging device of approximately 40,000 elements.

c. Extreme Ultraviolet Spectrometer.

d. Advanced Instrument Pointing system (Video Inertial Pointing System, for example) with at least 1 arc second stability).

This payload would serve as a test bed to test advanced instrumentation for both stellar and planetary observations.

The planetary observations will yield information on the presence, concentration and temperature of such XUV emitting gases or He, Ne, Ar, N, etc. The Solar observations will yield additional information about the composition, temperature, and motion of the solar atmosphere.

The technology demonstrated during this flight supports a large number of planned astronomy missions. No clear technology readiness date exists for this payload but a demonstration flight in 1985 would enable the technology to be utilized in 59 of the 107 astronomy payloads that contain extreme ultraviolet instrumentation and are scheduled for the 1981-1991 period.

Technology Advancement Required

Several technology advancements are required in the basic extreme UV telescope. Specific items to be addressed include active contamination control, reflective coatings, and narrow band pass filters.

There are many technology advancements that could be investigated in the deployment of the multiple instrument chamber. In addition to the increased sensitivity and 10^7 range required for the flux counting detectors there are significant reductions in telescope observing time that can be realized with higher resolution extreme ultraviolet imaging systems. The desired resolution imaging device appears to be a two dimensional array of 20,000 by 20,000 elements. This array of 4×10^8 elements represents the resolution of currently used ultraviolet film and is an extremely long range goal. For example, the Outlook for Space Technology Forecast would not forecast this capability until about the year 2040. However, a imaging system array of 40,000 elements listed as one of the payload elements represents a factor of 2.5 increase in current technology and should be ready for a 1985 flight demonstration.

The third element in this payload is an Extreme Ultraviolet Spectrometer. The major technological advancements requiring demonstration are:

a. One Angstrom Spectral Resolution

b. 300 to 1200 Angstrom Spectral Range

c. Sensitivity to about a minimum of 10^7 photons/sec/cm^2

The fourth element in this payload is the demonstration of an advanced astronomical pointing system of at least one are second stability for long periods (30 minutes).

Associated Mission Model

As mentioned previously, this Extreme Ultraviolet Astronomy payload would support 59 of the 107 astronomy missions containing extreme ultraviolet instrumentation planned between 1981 and 1991. Specifically, five flights of the Large Solar Observatory (AST-7), 34 flights of the Steller Sortie Mission (AST-10), and 20 flights of the Solar Sortie Mission (AST-11).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Extreme Ultraviolet (EUV) Spectrometer to Measure Planetary EUV Emissions from the Space Shuttle PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: S/C Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Sensitive high spectral resolution EUV spectrometer to study EUV emissions (i.e., He, Ne, Ar, N, etc.) in planetary atmospheres.

4. CURRENT STATE OF ART: Very poor - no EUV spectrometer has flown in the earth's atmosphere to measure planetary EUV emissions.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

High resolution spectral resolution (∿1 Å)

Spectral range ∿300-1200 Å

High sensitivity - be able to detect about 10 Rayleighs from Venus, Mars, Jupiter and Saturn (where 1 Rayleigh 10^6 photons cm^{-2} sec^{-1}).

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Fundamental knowledge concerning the composition and structure of the upper atmospheres of the planets and the evolutionary history of planetary atmospheres can be obtained with EUV measurements.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): EUV Spectrometer to Measure Planetary EUV Emissions from Space Shuttle

7. TECHNOLOGY OPTIONS:

N/A

8. TECHNICAL PROBLEMS:

The design of "optical" instruments in the extreme of vacuum ultraviolet.

9. POTENTIAL ALTERNATIVES:

Metallic-filter photometers work in the EUV spectrum. However, these Photometers have very wide bandwidths and are not very sensitive.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

LRC has jet feasibility contracts with Bendix Aerospace Systems Division and the Space Science Laboratory of the University of California at Berkeley to design a shuttle EUV spectrometer for planetary measurements.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

N/A

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.
1. TECHNOLOGY REQUIREMENT (TITLE): ____________________	PAGE 3 OF ___

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

F-2 INFRARED ASTRONOMY/COLUMN DENSITY MONITOR

Application

The Column Density Monitor is the first of three instruments and facilities aimed at using the Shuttle as a base for astronomical observations in the infrared, and especially the far-infrared (wavelengths above 30 microns). The second element will be a device referred to as the Advanced Technology Radiometer which is also being proposed as a Shuttle payload. The third element in this program will be the deployment and operation of large IR facilities and as the OSS Shuttle/Spacelab Infrared Telescope Facility (SIRTF).

The Shuttle/Spacelab Infrared Telescope, along with the Large Space Telescope, support the following Outlook for Space themes listed below:

08 The Nature of the Universe

09 The Origins and Fate of Matter

10 The Life Cycle of the Sun and Stars

11 The Evolution of the Solar System

Payload Description

"If infrared astronomical telescopes are to be used to their full advantage on the Space Shuttle, the column density of gas above the Shuttle payload bay must not exceed 10^{12} infrared-active molecules cm^{-2}. H_2O is the molecule of greatest concern because of its abundant offgassing from the Orbiter and its strong rotational and vibration-rotational spectrum which spans the infrared spectral range. Other molecules such as CO_2 and NO also contribute significantly to the IR background. In addition to the molecular line radiation there will be continuum radiation from the zodiacal light, stars, and contaminant dust particles. A cryogenically cooled radiometer with a 10 to 35 cm aperture, an array of 10 to 18 low noise detectors at the focal plane, a rotating, cold chopperfilter, and a well baffled enclosure could detect column densities of water at 270 K as small as 10^{10} cm^{-2}. By measuring the intensities of two bands of water with different temperature dependency both the column density and temperature can be determined. The information obtained by such an instrument will be very helpful in determining the most desirable operational modes of the Shuttle not only for IR astronomy but for sensitive UV and visible observations as well." (Reference NASA-SP-379).

The third stage development, The Shuttle Infrared Telescopic Facility is currently scheduled for Shuttle flight #21 which is to be launched in 1981. For the Column Density Monitor to be of maximum value it must be ready for one of the very first (1980) Shuttle flights.

Technology Advancement Required

Two areas of technology need advancement. These are, first, the development of a focal plane chopperfilter system is required to reject random thermal noise and thus obtain the required system sensitivity. Second, improvement in the performance modeling of instruments so that the contaminants and particles can be readily distinguished from the natural external ervironments. Additionally, data from some selected detectors could be enhanced if techniques to achieve temperature below $2^{o}K$ could be developed and demonstrated in space.

Associated Mission Model

This payload is in direct support of the Shuttle Infrared Telescope Facility which is scheduled to be launched in 1981.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Column Density Monitor for Infrared-Active Molecules

PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure the column densities, species, and temperatures of infrared-active contaminants in the vicinity of shuttle. Also to detect infrared-emitting particles.

4. CURRENT STATE OF ART: Existing techniques for measuring contaminants cannot provide the required combination of column density, temperature, and particle environment.

HAS BEEN CARRIED TO LEVEL 3/4

5. DESCRIPTION OF TECHNOLOGY

Sufficient analysis has been completed to define preliminary performance requirements (ref.) for determining the combination of column density, temperature, species and particle environment. Cryogenically cooled radiometers of the approx. aperture size (35 cm) exist and could be modified to accept a new chopped/filter and focal plane. A sensitivity of $10^{-15} W/Hz^{\frac{1}{2}}$ should be achieved over the range of 6 to 30 microns. A cooled, rotating chopper/filter and focal plane needs to be developed which is capable of the same sensitivity in the following bands: 6.0-6.1, 6.2-6.3, 6.4-6.5, 23.4-23.7, 23.7-24.0, 24.0-24.3, 28-29, 29-30, and 6-30 microns.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1. Shuttle contamination environment is a major concern of astronomers who are considering shuttle as a platform for telescopes.

2. Performance requirements are based on the need to verify that the contamination environment will not impair IR (emission) and UV (absorption and scattering) telescope performance. (Less than 10^{12} IR active molecules/cm^2 and less than one 5 micron or larger particle per orbit in a 15 arcminute field-of-view.)

3. Analysis of performance requirements shows existing cooled, IR radiometers can be used with modification. Chopper/filter and focal plane need development. Appropriate detectors are, or will be, available.

4. Technology needs to be demonstrated on early shuttle flights, concurrent with measurement of the contamination environment.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Column Density Monitor for Infrared-Active Molecules — **PAGE 2 OF 3**

7. **TECHNOLOGY OPTIONS:**

As described below (section 9), other known techniques cannot provide the combination of measurements required. Smaller apertures may be used, but would require the development of more sensitive detectors.

8. **TECHNICAL PROBLEMS:**

Major problems are the design and demonstration of the chopper/filter and the focal plane, cooling the focal plane to less than $10^{\circ}K$ and the optics to about $20^{\circ}K$, distinguishing individual contaminant and particle signals from each other and the external environment, and achieving the required NEP.

9. **POTENTIAL ALTERNATIVES:**

Other techniques for measuring contaminants include deposition rate, laser excitation, and measurement of solar spectrum. However, none of these techniques can provide combination of specie, column density, temperature, and particle environment.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

FY'75 funding received from Code RS for initial definition of a column density monitor. Some additional funding expected from OMSF (through Naumann at MSFC) for further definition. Hardware development and demonstration funding is required.

EXPECTED UNPERTURBED LEVEL 3/4

11. **RELATED TECHNOLOGY REQUIREMENTS:**

Spacelab astronomy payloads, especially IR.
Contamination
Cryogenics
IR detectors

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Column Density Monitor for Infrared Active Molecules

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Performance Requirements	---																		
2. Chopper/filter and																			
3. focal plane development		---																	
4. Preliminary Design		---																	
5.																			
APPLICATION																			
1. Design (Ph. C)			---																
2. Devl/Fab (Ph. D)				---															
3. Operations					---	---	---	-	- -	-									
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					x		?	?	?									
NUMBER OF LAUNCHES					2	3	2	2	2									11

14. REFERENCES:

F. C. Wittenborn, et. al., "A Radiometer for Monitoring Column Densities of Infrared-Active Molecules," Proceedings of the 8th Conference on Space Simulation, NASA SP-379

15. **LEVEL OF STATE OF ART**

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

F-3 INFRARED ASTRONOMY/ADVANCED TECHNOLOGY RADIOMETER

Application

The Advanced Technology Radiometer is the second stage development in a three element effort comprised of:

1. Column Density Monitor
2. Advanced Technology Radiometer
3. Shuttle Spacelab Telescope Facility

The overall objective of these efforts is to make Far-Infrared observations from the Shuttle in the wavelength region from 5 to 100 microns. These observations support the four Outlook for Space themes listed below:

08 The Nature of the Universe

09 The Origins and Fate of Matter

10 The Life Cycle of the Sun and Stars

11 The Evolution of the Solar System

Payload Description

The Advanced Technology Radiometer payload will attempt to package significant technology improvements from three different technical disciplines. The payload will build on expected earlier experience with the Column Density Monitor and, in fact, use some of the same hardware. First, improvements in IR detectors are to be tested as well as advanced chopping or encoding techniques. Second, by integrating the Advanced Technology Radiometer with the Video Inertial Pointing System a space test of that system can be implemented while accomplishing a significant number of Science objectives. Third, improvements in both the basic thermal performance and noise control of the low temperature (1 to $10^{o}K$) cooling device used for the Column Density Monitor will be incorporated. Ideally, the Advanced Technology Radiometer payload would follow the Column Density

Monitor by about one year. It would contribute significant technology to the Shuttle Infrared Telescope Facility which is SSPD Mission Model Payload #AS-01-S. Payload #AS-01-S is tentatively scheduled for 61 sortie flights between 1981 and 1991. The technology advancements demonstrated in the Advanced Technology Radiometer could be incorporated into the basic #AS-01-S payload about 1984 with 54 of the 61 flights remaining. Ideally, the Advanced Technology Radiometer Payload would have a late 1981 launch date.

Technology Advancement Required

As mentioned previously the following technology advancements are required:

a. Far Infrared Detector Elements

b. Focal Plane Encoding Techniques

c. Video Inertial Pointing System

d. Low Temperature (less than 10^{O}K), focal plane cooling device and a moderate temperature (less than 30^{O}K) cooling device for the optical elements.

All the technology advancements listed above are required for incorporation into the Advanced Technology Radiometer by 1980 except the low temperature cooling device which should be ready by 1979 to match the flight date for the Column Density Monitor.

Associated Mission Model

The Advanced Technology Radiometer Payload would directly support Payload #AS-01-S of the 1973 Mission Model which is the basic astronomy sortie package.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Technology IR Radiometer PAGE 1 OF ___

2. TECHNOLOGY CATEGORY: Sensors, Pointing and Stabilization, Cryogenics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Shuttle-borne test bed for flight testing advanced IR technology as an astronomical telescope/sensor systems.

4. CURRENT STATE OF ART: IR radiometer of the approximate size and sensitivity have been developed for the AF, but lack of flexibility required for a test bed. HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY A radiometer is needed to provide a satisfactory test bed for advanced detectors, focal plane configurations, chopping methods, pointing and stabilization techniques, cryogenic cooling methods, and operational procedures. Such a radiometer should meet the following specifications with advanced detectors:

1.) NEP in any 10 micron band for a 1 arc min. FOV
10^{-17} $w/Hz^{\frac{1}{2}}$ for 5-30 microns
10^{-16} $w/Hz^{\frac{1}{2}}$ for 30-100 microns
10^{-18} $w/Hz^{\frac{1}{2}}$ for 5-30 microns with diffraction limited FOV

2.) Diffraction limit at 5 microns, aperture diameter about 30 cm, space chopping, off-axis rejection to allow pointing to within 45^o of sun and 30^o of moon.

3.) Cryogenic cooling to achieve NEP's (1-10^oK at focal plane and (30^oK at optics)

4.) 3-axis gimbals

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a.) Requirements based on detailed analysis of technology needs for future large IR telescopes. A current study at Ames is further defining requirements and determining whether the proposed column density monitor could be upgraded to meet these requirements.

b.) Benefiting IR payloads include the large, cooled Shuttle Infrared Telescope Facility, large ambient IR telescope, and IR free-flyers. Other payloads will benefit from cryogenic and pointing technology.

c.) Time required to acquire scientific data is proportional to the square of the achieved NEP, therefore improved detectors and cooling greatly increase amount of data from a given flight. Advanced pointing techniques and optional procedures will increase time on-target and astronomer interaction.

d.) Technology must be demonstrated on shuttle in an observing mode.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT | NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Advanced Technology Radiometer | PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

1.) Various advanced detectors could be tested prior to final selection

2.) Various encoding techniques could be modeled (Hadamard, for example)

3.) The planned SIPS (Small Instrument Pointing System could be used instead of the Video Inertial Pointing System)

8. TECHNICAL PROBLEMS:

1.) Noise control on cryogenic cooler

2.) Extreme temperatures

3.) Contamination of optical surfaces

9. POTENTIAL ALTERNATIVES:

1.) Higher technological risk for following cryogenic telescopes (Shuttle Infrared Telescope Facility)

2.) Lower performance of cryogenically cooled telescopes through the use of state of the art detectors.

3.) Longer observing times by using state of the art technology.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

1.) 1-10^{o}K cooling device

2.) Column Density Monitor

3.) Longer observing times by using state of the art technology

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Technology Radiometer PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. IR Detector Development	---	---	---	---	Continuous	---	---	---	---	---	---	---	---	---	---	---			
2. 1-10°K Cooler Dev.		---	---	---															
3. Video Inertial Pointing System	---	---	---	---	---														
4. Encoding Techniques	---	---	---	---	---														
5.																			
APPLICATION																			
1. Design (Ph. C)	---				---														
2. Devl/Fab (Ph. D)						---													
3. Operations							---	---											
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES										6	8	6	6	8	6	6	8	54

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Detectors and Detector Arrays for the Far Infrared (Wavelength Longer than Thirty Microns) PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: ____

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased sensitivity and increased data accumulation needed to fully realize the capabilities of a shuttle-borne infrared telescope.

4. CURRENT STATE OF ART: Present long wavelength detectors exist with noise equivalent power (Nep) of 10^{-14} watts $Hz^{-\frac{1}{2}}$. Shortward of 30 microns, suitable detectors (developed for military applications) exist. HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

The detectors required to utilize the inherent sensitivity of a Shuttle-borne telescope must have an Nep of 10^{-16} watts $Hz^{-\frac{1}{2}}$ or better at wavelenths longward of 30 microns. In order to reach this sensitivity materials and fabrication techniques for photoconductors and bolometers must be developed. Low noise cooled preamps must be developed. Refrigeration to $0.1^{\circ}K$ in zero gravity must be developed for proper operation of the bolometers. The techniques to fabricate detector arrays with integrated electronics are needed.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a.) The 10^{-16} watts $Hz^{-\frac{1}{2}}$ Nep level is based on the requirements of infrared astronomy and the background limitations expected at a shuttle telescope facility.

b.) This technology will benefit all investigations involved in infrared detection at long wavelengths. This includes survey satellites, shuttle-borne infrared telescopes and the LST when used for IR astronomy.

c.) Other things equal, then the time required to accumulate meaningful scientific data is directly proportional to the square of the detector Nep. Therefore, improved detectors greatly increase the amount of data obtained per flight.

d.) This technology advancement should be carried to level 7.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Detectors and Detector for the Far Infrared (Wavelength Longer than Thirty Microns). PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Alternatives to improved detectors are larger telescopes and longer observing times. Both are limited by technical and economic considerations.

8. TECHNICAL PROBLEMS:

1.) Development of suitable materials and "doping" techniques for long wavelength photoconductors and low temperature bolometers.
2.) Development of low noise, low temperature preamps.
3.) Development of low temperature ($0.1^{o}K$) refrigerators for zero gravity.
4.) Development of integrated electronics for reading out arrays.

9. POTENTIAL ALTERNATIVES:

Same as (7).

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

There exist ongoing development of detectors for short wavelengths for military applications. Some development requiring further funding exists at universities.

EXPECTED UNPERTURBED LEVEL 3/5

11. RELATED TECHNOLOGY REQUIREMENTS:

He^3/He^4 dilution refrigerators for $0.1^{o}K$ operation in zero gravity.
Low noise, low temperature preamps.
Electronic components and circuits for storing data from arrays between readouts.
Narrow pass, high efficiency filters.
Spectrometers.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Detectors and Detector Arrays for the Far Infrared (Wavelength Longer than Thirty Microns) — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses	--	--	--																
2. Fabrication		--	--	--															
3. Ground Testing		--	--	--															
4. Flight Testing				--															
5.																			
APPLICATION																			
1. Design (Ph. C)				--															
2. Devl/Fab (Ph. D)					--														
3. Operations						--													
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

Astronomy and Astrophysics for the 1970's. Vol 2 National Academy of Sciences, 1973.

A long range program in Space Astronomy. NASA SP-213, July 1969.

Study to Compile Available Information for a Space Shuttle Mounted Infrared Telescope. Contract #NASA 2-7313, Martin Marietta, 1973.

Large Space Telescope - a New Tool for Science. AIAA Aerospace Sciences Meeting, Feb. 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

SECTION G: CONCLUSIONS

The workshop results should be considered as the beginning of a process to relate advanced technology to potential Shuttle payloads. The earlier this association is made, the more effective will be the investment in advanced technologies.

Much work remains to be done with the product of the workshop. Studies should be initiated to explore trade-offs available by alternate approaches. The level of definition needs to be deeper. Multidisciplinary payload integration should be actively pursued.

The major thrusts appear to be well chosen, highly relevant to the issues to be faced. This relevance is noted in the following examples of payload/major thrusts relationships:

Payload B-1 - Stratospheric Trace Gas Effects are directed towards an advanced limb-scanning radiometer for measuring the difficult trace species such as chlorine products which threaten stratospheric ozone. The measurement requires detector sensitivity one to two orders of magnitude beyond that currently available. The major thrust statement concerning increased mission output through improved sensing performances is relevant to this payload and associated advanced technology need.

Payload C-1 - Coastal Zone & Land Resource Management discusses advanced concepts of image processing needed to handle the high data rate associated with advanced multispectral scanners. One concept would use fast on-board microprocessors, closely integrated with the sensor output. Another concept would perform direct image processing using Fourier transform imagery which could perform pattern recognition, data compression and spatial frequency analysis. The major thrust statement concerning the reduction of information system cost by extensive integration of sensor and processing technology is relevant to this payload and associated advanced technology need.

Payloads D-1 through D-3 - Concerning Advanced Microwave Radiometer and Radar Systems, are meant to apply microwave systems to global survey of ocean surface characteristics, crop survey, soil moisture and rainfall. These payloads are highly relevant to the major thrust statement concerning global surveys through multipurpose, all-weather, active/passive microwave systems. The payloads are also relevant to the other two major thrust statements discussed above.

COMPILATION OF

ADVANCED TECHNOLOGY REQUIREMENTS

Report II of the
Sensing and Data Asquisition Working Group

OAST Space Technology Workshop

August 15, 1975

A. INTRODUCTION

This part (Report II) of the total report will cover those advanced technology requirements that did not have a sensible development approach as part of a payload in Report I. Even so, some of the requirements mentioned below may receive significant development support from a payload in Report I and this will be noted.

The technology requirements below come from "grassroots" material submitted from the Centers through the Working Group members, the users as represented in the OA and OSS parts of Reference 1, and conversations with members of the User Working Group and others during the course of the Workshop. A title or a title with some paraphrase of user terminology is used to note the technology needed. "Definition of Technology Requirement" forms, where submitted, are noted by a reference to the Appendix containing them.

The requirements are recognized to be incomplete and, as they are stated below, vary considerably in scope and specificity of technology required. This is to be expected considering the broad scope of technology inherent in the sensor area, the diverse viewpoints and backgrounds of the users, and the lack of knowledgeable Workshop personnel in some areas.

The organization of the material follows the remote, particles and fields, and in-situ properties instrument outline proposed at the beginning of the workshop and groups similar technology within those areas. Components that might be used with several instruments are identified with the instrument system where their primary need appears.

B. REMOTE SENSING SYSTEMS

By definition, this group of instruments will be those measuring properties of electromagnetic radiation with the general user interest in understanding the properties of the source or medium along the radiation path.

1. Microwave and Radar

The basic needs for this technology are for Earth and planetary observations and this is well represented in the payloads in Report I. The submillimeter development for astronomy is a part of such a development payload.

Needs that may not be covured are:

a. Lunar Orbiter Radar Altimeter

The performance needed is not available for this report and may very well overlap Earth and planetary Orbiter observation requirements.

2. Lasers

The basic needs for earth applications are represented in the payloads of Report I.

Not included are:

a. An Improved Ground-Based Lunar Laser

(See page 25 of the OSS part of Reference 1 for current performance).

3. Imaging Systems

Multispectral imaging developments for earth, planetary, and lunar orbital observations are included in payload deve opments in Report I. Some of the array detectors for Astronomy will be helped as well.

Other needs are as follows:

a. Advanced Large Space Telescope

Photometry of 29th magnitude object and imagery of 25th magnitude is required. Large Space Telescope (LST) will perform at 27th and 23rd magnitude respectively with 2.4 m telescope. An approach is a 5-6 m diffraction limited telescope.

b. Large Array X-Ray/UV Detector

Arrays with 20,000 X 20,000 elements of about 10 m size are needed as focal plane detectors in the spectral range from 9 to 2000 A. Each element should have single photon sensitivity with counting dynamic range of 10^7.

c. Panoramic Imaging System for Venue

High pressure (100 Atm) and temperature (300°K) environment with limited lifetime.

4. Radiometers and IR Instruments

This technology is well represented in the payloads of Report I. Additional needs are:

a. Solar Flux Detector

The device should be stable for a year and accurate to 0.1% and cover the spectrum for direct solar observations.

b. High resolution IR Spectrocopy for Astronomy

c. Pressure Modulated Gas Cell Detector

Operation at pressures up to several atmospheres for use with correlation radiometer to measure tropospheric pollution.

d. Josephson Junction Detectors

e. Sensitive Pyroelectric Detectors for far IR

5. X and Gamma Ray Instruments

This technology is not directly represented in the payloads in Report I. However, Physics and Astronomy development payloads for Shuttle are described in Reference 2 and 3 and are briefly discussed at the conclusion of this report.

a. High Resolution (1.0") X-Ray Imaging Device

b. Large (2.2 M) Grazing Incidence X-Ray Optics

c. High Areal Resolution Gamma and X-Ray Spectrocopy

This is needed for lunar composition mapping to about 10 km and is a technique applicable to other airless bodies.

C. FIELDS AND PARTICLES

With minor exceptions, this area does not have direct representation in the payloads of Report I and only a few items were presented to the Workshop.

1. Electric Fields

a. Spacecraft Charge and Potential

The requirement is to keep the spacecraft neutral and at equipotential,

b. Potential Measurement

New concepts are needed to make synoptic measurements of potential from one to 10 millivolts per meter.

2. Magnetic Fields

(No Entries)

3. Charged Particles

a. Plasma Measurement Beyond 8 A. U.

(See Appendix, Item 8)

b. Silicon Surface Barrier Detector

(See Appendix, Item 10)

D. IN-SITU PROPERTIES

This group includes the direct geophysical, geochemical, and atmospheric measurements and are not represented in nor appropriate to the development payloads in Report I.

1. Geochemical

The first three classes of instrumentation below have been under development at one time or another since the beginning of the lunar program and are of interest for future lunar missions, on other airless bodies and on the terrestrial planets.

a. Age Determination

This is an extremely difficult problem and may not be possible in the foreseeable future. The alternative is sample return.

b. Petrographic Analysis

This is difficult but may be feasible. The alternative is sample return.

c. Elemental Analysis

Some approaches have been demonstrated and others need development.

d. Comet Gas and Dust Collection and Analysis

This is an essential development for a comet mission.

2. Geophysical

a. Geophysical Instrumentation

b. Seismic Wave Generators

Needed for safe remote planetary operation.

3. Atmospheric

a. Jupiter Probe Atmospheric Instruments

Pressure, temperature, and composition measurements at 1000 bars. 1500°K, and hours long duration.

b. Aerosol Measurements of Small Diameter Particles

(See Appendix, Item 2)

c. X-Ray Fluorescence Analysis of Aerosols

(See Appendix, Item 3)

d. Stratospheric Trace Radical Detector

(See Appendix, Item 9)

E. SUPPORTING RESEARCH AND TECHNOLOGY

The items collected here appeared to need research or the special attention of other Working Groups.

1. Accurate Mass position detectors (10^{-20})
2. Accurate orbital dock (10^{-17})

3. Time lapsa measurement (10^{-12}sec.)

4. Large ($> 10\ cm^2$) thin (micron) films

5. Long-life (2-3 year) cryogenic systems

6. Superconducting Instrumentation and Sensor Research

(See Appendix, Item 7)

7. Sub-Ocean Current and Topography Sounding from Space

New approaches and techniques are needed.

8. Direct Gravity Field Measurements

New approaches and techniques are needed for measuring Earth's field in space.

9. Penetrometer Delivery System and Alternatives

Needed for lunar, outer planets satellite and terrestrial planet investigations.

10. Advanced Sampling Systems

To be used with petrographic and geochemical analysis in general, support of in-situ measurement missions.

11. Near-Ground Pollution Detection Techniques

Laser and lidar are current approaches to the problem. New techniques may be needed.

12. High accuracy Accelerometers

These are needed to assess drag forces on gravity study satellites.

13. Accurate Location of Continents (Centimeters)

Refinement of the current long baseline interferometer approach should accomplish this objective.

14. Radiative Refrigerator for IR Detectors

(See Appendix, Item 5)

15. Molecular Beam Mass Spectrometer

(See Appendix, Item 1)

16. Development of Optical and Acoustical Homodyning Techniques

(See Appendix, Item 6)

17. Visual Range Technique for Airfields

(See Appendix, Item 4)

18. Low Cost ($500) Device for Position Determination

This device is to be used in conjunction with a satellite as a system to detect changes in position between different points on earth.

F. CONCLUSIONS

All the significant earth application technology needs appear to be covered in Shuttle development payloads in Report I.

Most of the basic technology development needs for planetary remote sensing are included in the payload developments in Report I. Many of these sensors are driven primarily by earth application needs. The low weight and power, long lifetime, functional performance, and other peculiar needs of the planetary program can often be helped at little extra cost with knowledgeable attention early in the development cycle.

Much of the Physics and Astronomy technology is not directly reflected in the development payloads in Report I. There are extensive flight instrument developments planned for Shuttle sortie missions and it is expected that these payloads will serve many of the same functions for Physics and Astronomy as the payloads in Report I serve for the Applications area. As a result, the items shown in this part of the report are largely basic research and developmental items.

Because of the nature of the in-situ measurements, their technology is not represented in the development payloads of Report I. Without new ideas and further development of some old approaches, geochemistry of remote bodies will only be possible through sample return.

References

1. "1975 NASA OAST Workshop Overview Report"

2. "The 1973 NASA Payload Model" June 1973

3. "A Program for High Energy Astrophysics (1977-1988)", Ad Hoc Planning Group of the High Energy Astrophysics Management Operations Working Group, July 15-18, 1974.

APPENDIX

Report II

of the

Sensing and Data Acquisition Working Group

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Molecular Beam-Mass Spectrometer PAGE 1 OF 6

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To design, develop, and fabricate a mass spectrometer applying molecular beam techniques to minimize inaccuracies caused by gas-surface interaction effects for density measurements in (cont)

4. CURRENT STATE OF ART: Theoretical and experimental studies (refs. 1 and 3) have demonstrated the feasibility of the molecular beam-mass spectrometer concept. Most of the mechanical (cont) HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Technical Approach - In making mass spectrometric density measurements, it is obviously desirable to obtain an unaltered sample of the gas and to maintain the integrity of this sample during the measurement. In those cases where the instrument is embedded in a high velocity gas, such as in a molecular beam or on a rocket probe or satellite, an unaltered sample can be obtained and measured by continuously passing the gas through a highly transparent ionization volume where a fraction is ionized, focused into a mass analyzer, and counted. Geometrical criteria obtained from the kinetic theory of a drifting Maxwellian gas have been applied to the instrument design to insure that the unused fraction of the beam is returned to the stream with a negligible probability of molecules backscattering into the ion source. This technique thus determines constituent density from an undisturbed (unaltered) gas sample since molecules which have collided with any instrument surface do not appear in the ionization volume.

The requirements of minimizing scattering in the ion source are satisfied by a small-angle (cont)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Justification - Mass spectrometric measurements in high velocity streams, molecular beams, gas-surface interaction experiments, and gas-gas interaction experiments frequently encounter substantial ambiguities in data interpretation. The measured data frequently yield gross inaccuracies in molecular density and molecular composition, and even yield spurious molecular species. The common source of these errors is interaction between the instrument and the gas being measured. Chemically active species interact with the instrument surfaces where some of the species in the measured gas are lost and from which spurious species are injected into the measured gas. The methods which have been used in the past in an attempt to solve these problems have either yielded very limited improvements or have been limited to a very narrow range of applications.

Accurate measurements of the atmospheric constituents in the thermosphere of the planets are extremely difficult, due to the presence of significant quantities of reactive gases such as atomic oxygen. It has been shown that most published terrestrial mass spectrometric densities for this gas are in error by as much as 400 percent. These errors result from composition and density changes associated with gas-surface interactions and are inherent in conventionally designed mass spectrometers. With existing instruments, these errors can only be minimized by using cryogenic cooling techniques which are not applicable to long lifetime experiments. (cont)

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Molecular Beam-Mass Spectrometer

7. **TECHNOLOGY OPTIONS:**

Mass spectrometric measurements give both the type and quantity of the gas present. No other instrument technique has this capability for low density gas measurements.

8. **TECHNICAL PROBLEMS:**

There are no problems with the principles involved in this instrumentation system. Detailed solutions have been worked out for the practical problems encountered in the development of this sensor.

9. **POTENTIAL ALTERNATIVES:**

None

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

750-01-51-01	Molecular Beam Laboratory
179-30-23-01	Molecular Shield Vacuum Facility
185-47-92-01	Thermospheric Measurements

If NASA continues the resources for this sensor at its present level, components and breadboards could be tested in the laboratory by the time Shuttle flies.

EXPECTED UNPERTURBED LEVEL 5

11. **RELATED TECHNOLOGY REQUIREMENTS:**

All the technology requirements have been included in the development program for this instrument.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Molecular Beam-Mass Spectrometer PAGE 3 OF 6

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design: Mechanical / Electronic																			
2. Fabrication																			
3. Calibration/FAT																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations					Shuttle Operational														
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						X												
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. Melfi, L. T. , Jr.: The Design, Development, and Analysis of a Mass Spectrometer System for Number Density Measurements in the Terrestrial Thermosphere. A Dissertation submitted to the Dept. of Meteorology, Florida State Univ., in partial fulfillment of the requirements for the degree of Doctor of Philosophy, August, 1971.
2. Clay, F. P., JR.; Brock, F. J.; and Melfi, L. T., JR.: The Emission Efficiency of a Hot Filament in the Presence of O_2 at Various Pressures and Techniques for Maintaining Constant Emission. Presented at Virginia Academy of Sciences Meeting, May 1-4, 1973. Abstract published in Virginia Jour. of Science, Vol. 24, No. 3, Fall 1973.
3. Melfi, L. T., JR.; and Brock, F. J.: Molecular Beam Techniques Applied to Mass Spectrometer Thermospheric Density Measurements. Rev. Sci. Instrum., Vol. 44, No. 10, October, 1973.
4. Melfi, L. T., JR.; Brock F. J.; and Brown, C. A., JR.: A New Approach to Thermospheric Mass Spectrometric Density Measurements. NASA TN D-7711, 1974.

(cont)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Molecular Beam-Mass Spectrometer

3. OBJECTIVE/ADVANCEMENT REQUIRED (concluded): Molecular beam laboratories and in planetary atmospheres.

4. CURRENT STATE OF ART (concluded): COMPONENTS of the mass spectrometer have been designed and are being fabricated (ref. 7). A laboratory model of the ion source has been evaluated (refs. 6 and 7). Several electronic circuits have been breadboarded and evaluated including a very low power emission control circuit (refs. 2 and 5). A flight evaluation experiment on a Scout or Delta (piggyback) in the terrestrial thermosphere has been shown to be feasible (ref. 4).

5. DESCRIPTION OF TECHNOLOGY
Technical Approach (concluded): truncated cone constructed of high transparency mesh ($\gtrsim 0.95$), the enclosed volume of which is the ionization volume. (See fig. 1, ref. 3). At low density, multiple scattering may be neglected. Thus, gas scattered from the external surface never enters the ionization volume for any gas-surface scattering law, provided that the external surface of the support structure is a smooth continuation of the ion source grid structure. The ions extracted from the ionization volume are focused by an electrostatic lens onto the quadrupole entrance aperture. In the process of ion-beam formation and extraction, the ions are accelerated to a velocity which is large compared with the thermal velocity of the neutral gas. This minimizes the dependence of the distribution of ion-beam current density on gas temperature and small variations in angle of attack. The lens is located inside the support cone and its angular aperture is sufficiently large to allow only a small fraction of the neutral beam to collide with its surface. The quadrupole entrance aperture is located sufficiently far downstream to provide adequate exhaust area. The cathode is a wire ring with a small cross section surrounding the ion-source grid and is located slightly aft of the grid base to minimize the probability that gas scattered from the cathode may enter the ionization volume.
Future Plans - The mass spectrometer development activity may be conveniently divided into two categories: 1. Mechanical and 2. Electronic.
Mechanical: The components of the mass spectrometer consists of an ion source, quadrupole mass analyzer, and electron multiplier. The design of these components has been completed and laboratory prototypes of most have been fabricated. Experimental results from laboratory evaluation have been incorporated into the design. Fabrication techniques have been developed during construction of the laboratory prototype components.
A flight prototype ion source and lens will be fabricated using proven materials and fabrication methods. The performance of the ion source will be experimentally evaluated to establish the energy distribution and angular distribution of the extracted, focused ion-beam and to determine the source sensitivity for optimum electrical parameters.
A flight prototype hyperbolic quadrupole will be assembled. The rod surfaces and ceramic holder have been machined to a tolerance of 0.0001 inches and similar precision is required in assembly and alignment. An optical method has been developed to verify that the required precision has been achieved in the final assembly. After assembly, the quadrupole will be evaluated using the extracted ion-beam from the source-lens system. Resolution and sensitivity will be measured as a function of atomic mass units to determine the operational characteristics of the combined system.

A laboratory prototype electron multiplier will be fabricated and its performance experimentally evaluated. The electron multiplier design is based on experimental results obtained from studies of simulated electron trajectories in a number of dynode models. The multiplier has axial symmetry with off-axis dynodes and an on-axis photon trap. Results from the performance evaluation of the laboratory prototype will be incorporated into the design and a flight prototype multiplier fabricated.

Electronic: The electronic components of the mass spectrometer consist of ion source control circuits, quadrupole ac and dc voltage generators, dc to ac voltage ratio control circuit, mass selector circuit, electron multiplier voltage circuit, pulse height discriminator circuit, pulse counting circuit, and encoder circuits. Each component requires circuit design, circuit development by breadboarding and laboratory testing, flight packaging, and flight acceptance testing.

Efficient control circuits for the ion source have been developed and their performance has been evaluated. These circuits will be flight packaged and acceptance tested.

The quadrupole dc generator has been developed and its performance evaluated. This circuit will be flight packaged and acceptance tested.

Several quadrupole ac generator circuits are under parallel development. This work will continue until the required waveform purity and the required frequency and amplitude stability have been achieved. The circuits will be flight packaged and acceptance tested.

The mass selection circuit has been developed and its performance evaluated. It will be flight packaged and acceptance tested.

The remainder of the circuits are under development using commercially available sub-circuits wherever possible.

After evaluation and fabrication of the mechanical components have been completed, the mass spectrometer will be assembled, combined with the breadboarded electronic circuits, and evaluated as a system. Following this evaluation, flight acceptance tests and calibrations will be performed to give a mass spectrometer ready for flight.

6. RATIONALE AND ANALYSIS

Justification (concluded) - The mass spectrometer system described here has been designed to substantially eliminate those problems associated with gas-surface interactions in the instrument. The theoretical foundation for the instrument is firmly based on sound physical principles since the concept was developed from an application of the kinetic theory of a drifting Maxwellian gas to the measurement problem. The instrument is capable of measuring the absolute density of the molecular composition in high velocity streams, molecular beams, gas-surface interaction experiments, and gas-gas interaction experiments. The instrument reduces to a negligible level the probability that gas-surface interactions in the instrument will contribute to lost species, ambiguities, or spurious species in the measured data.

Payloads - A number of low density gas physics payloads are planned for the Spacc Shuttle. These include a Molecular Beam Laboratory for physics and chemistry. experiments and a Molecular Shield Vacuum Facility for materials processing. Further, the Shuttle offers a natural scientific platform from which the terrestrial upper atmosphere can be studied in real time. The sensor

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Molecular Beam-Mass Spectrometer PAGE 6 OF 6

described in this document will play an essential role in the implementation of these payloads. The instrument, as designed, will make minimum demands on the payload for services, is reliable, and has an indefinite lifetime. The mass spectrometer should be flight evaluated before the Shuttle is operational.

14. REFERENCES (concluded):

5. Clay, F. P., Jr.; Brock, F. J.; and Melfi, L. T., Jr.: A Switching Regulator Emission Control Circuit for Ion Sources. Rev. Sci. Instrum., Vol. 46, No. 5, May 1975, pp. 528-532.

6. Clay, F. P., Jr.; Melfi, L. T., Jr.; and Brock, F. J.: Evaluation of a Thoria Coated Iridium Cathode for an Ion Source. Presented at Virginia Academy of Sciences 1975 Annual Meeting, Harrisonburg, Va., May 6-9, 1975. Abstract published in Virginia Jour. of Sciences.

7. Melfi, L. T., Jr.; Outlaw, R. A.; Hueser, J. E.; and Brock, F. J.: Gold Plating-Brazing of Ion Source Components. Presented at Virginia Academy of Sciences 1975 Annual Meeting, Harrisonburg, Va., May 6-9, 1975. Abstract published in Virginia Jour. of Sciences.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Aerosol Measurements of Small Diameter Particles PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To measure aerosols of diameter 0.04 μm to 0.25 μm.

4. CURRENT STATE OF ART: Present measurement capability is for very small particles < 0.04 μm and for particles > 0.25 μm.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Light scattering techniques can measure in-situ particles greater than 0.25 μm by scattering light from individual particles as they are drawn through a scattering chamber. A photodetector measures the intensity and relates it to a nominal size.

Aiken nuclei counters measure particles < 0.04 μm utilizing the Wilson cloud chamber technique of the rapid growth of particles in a super saturation. The transmission through the cloud is related to concentration.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

A technique to measure this size range would provide valuable data on particle that are optically active affecting radiation transfer and are in a critical size range for studying growth mechanisms.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Aerosol Measurements... PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

The "Whitby" diffusion technique has some promise for measuring this size range.

8. TECHNICAL PROBLEMS:

Light scattering at these sizes is very weak.

9. POTENTIAL ALTERNATIVES:

None

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

None

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Aerosol Measurements... PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design																			
2. Breadboard																			
3. Testing																			
4. Fabrication																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

"Aerosols and Atmospheric Chemistry"; edited by G. M. Hidy, Academic Press (1972).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Elemental Analysis PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: Laboratory or field capability for the elemental analysis of single aerosols.

4. CURRENT STATE OF ART: Currently elemental analysis such as X-Ray fluorescence techniques are limited to atomic numbers greater than sodium.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

This technique allows the elements of a collected sample to be identified from the energy spectrum of X-Rays emitted when the sample is exposed to a beam of X-Rays. The energies of the X-Ray fluorescence are characteristics of the particular elements involved.

Elements with atomic numbers less than 12 are not detected by this method because of the energies of the emitted X-Rays are too low to penetrate the windows of commonly available detectors.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

This technique could be used to evaluate rocket effluent or pollution samples for their elemental composition and aid in benchmaking and determination of the effects of Shuttle effluents on the environment.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Elemental Analysis — **PAGE 2 OF 3**

7. **TECHNOLOGY OPTIONS:**

Use of proton scattering for this analysis where it possibly has the capability for lower atomic numbers.

8. **TECHNICAL PROBLEMS:**

Measuring low energy X-Rays.

9. **POTENTIAL ALTERNATIVES:**

None

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

RTOP #506-21-68 is supporting the measurement and impact of Shuttle effluents.

EXPECTED UNPERTURBED LEVEL ___

11. **RELATED TECHNOLOGY REQUIREMENTS:**

None

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Elemental Analysis — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design																			
2. Breadboard																			
3. Test																			
4. Fabrication																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

"Effluent Sampling of Scout "D" and Delta Ve[illegible]e Exhausts"; by W. C. Hulten, et. al., NASA TMX-2987, July 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): RVR & SVR — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensing and Data Acquisition

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop a single ended technique for measuring runway visual range (RVR) and slat visual range (SVR).

4. CURRENT STATE OF ART: No satisfactory technique exists.

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

From the ground a measurement (single-ended) of RVR and SVR is needed. Transmissometers and series of lights are not adequate, not representing conditions throughout the airfield area. Ceilometers give an indication of cloud ceiling, but nothing is available for glide path measurement of SVR.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Need for every airfield in the world.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** RVR & SVR — **PAGE 2 OF 3**

7. TECHNOLOGY OPTIONS:

None

8. TECHNICAL PROBLEMS:

1. Multiple scattering.
2. Large optical depths.
3. Eye safety.
4. Representative measurement (e.g. due to patchiness).

9. POTENTIAL ALTERNATIVES:

Possibly lasers working in eye-safe regions of spectrum (1.54 μm) or low energies.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP #502-23-56-03 supported feasibility analysis.

RTOP #505-08-22 is supporting continuation of work.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Detectors at 1.54 μm with sufficient response and gain.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): RVR & SVR PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Feas. Analysis																			
2. Design & Breadboard																			
3. Field Measurement																			
4. Fabrication																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. "MIE Scattering by Three Polydispersions," by F. S. Harris, Jr. and M. P. McCormick; Journal of Colloid and Interface Science, 39, pp. 536-545, June 1972.

2. "Lidar Techniques for Pollution Studies," by M. P. McCormick and W. H. Fuller, AIAA Journal 11, pp. 244-246, Feb. 1973.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Radiative Refrigeration Design

2. TECHNOLOGY CATEGORY: Infrared Detector Refrigeration

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased sensitivity of infrared systems used in orbital applications for remote sensing of environment.

4. CURRENT STATE OF ART: Several designs for passive systems have been used, but evaluations and design tasks have not been attempted for lack of opportunity.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The sensitivity of infrared detectors is dependent on the attainment and maintenance of very low temperatures - near liquid nitrogen. The practical approach to this requirement for long term missions is to utilize passive radiative refrigeration systems. The operation of these hinges on the temperature difference between outer space and the object requiring cooling. Several designs have been used in an attempt to accomplish the required results. These efforts have met with moderate success. A new system based on a comprehensive evaluation of current approaches concurrent with a design effort would provide increased infrared detection sensitivity.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Currently used infrared detectors require temperatures in the range of 80 degrees Kelvin.

b. Development of this system would benefit satellite designs of the ERTS-c type. In some applications, the Themmatic Mapper would benefit.

c. Present designs provide temperatures in the 195°K range with theoretical predictions down to about 100°K. Improvements would result in greater ground target thermal resolution, probably by an order of magnitude.

d. This technology advancement should be carried to an experimental demonstration in an early Shuttle flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Radiative Refrigeration Design

7. TECHNOLOGY OPTIONS:

The effectiveness of passive refrigeration devices relate to the ability of the system to radiate into outer space. This is a materials, as well as a geometry problem. It is proposed that a pallet of several designs be simultaneously evaluated in a modular/adjustment configuration permitting real-time interactive modifications.

8. TECHNICAL PROBLEMS:

1. Thermal path between infrared detector and refrigeration system.
2. Ability of system to radiate into outer space (Radiator Design).
3. Pointing of system into outer space.

9. POTENTIAL ALTERNATIVES:

Possibly using adsorptive pumping techniques using solar energy for power input in a conventional refrigeration cycle.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Current research by JSC for development of adsorption pumping techniques for use in cryogenic refrigeration purposes.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Infrared detector technology, low temperature technology, remote sensing technology.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Radiative Refrigera[illegible]ion Design PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Mechanical & Thermal Design																			
3. Fabrication																			
4. Test																			
5. Documentation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES						2	3	2	1									8

14. REFERENCES:

"Infrared System Engineering" by Richard D. Hudson, Jr. 1969.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Coherent Detection PAGE 1 OF 3

Optical and Acoustical Homodyning Techniques

2. TECHNOLOGY CATEGORY: Level 2 & 3 Coherent Detection

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop reliable laser & acoustical coherent detection systems for remote probing. (Acoustical for the remote non-destructive probing of astronauts' cardiovascular systems in space. Laser for measuring particle velocities in Shuttle environment & eventually on surfaces of other solar bodies.

4. CURRENT STATE OF ART: Off the Shelf coherent laser systems for measuring particle velocities are presently available but have severe limitations. No suitable off the shelf coherent acoustical systems are presently available.

HAS BEEN CARRIED TO LEVEL 1

5. DESCRIPTION OF TECHNOLOGY

Coherent detection of tracer velocities to describe fluid motions appears to have great potential for monitoring and measuring contaminate flows, fluid velocities, and blood flow (non-surgical, non-destructive remote measurement of blood flow velocities in cardiovascular systems). Laser systems along with the theoretical backup could provide a means of continuously measuring surface winds on suitable solar bodies, as well as particle concentration and distribution within the Shuttle. Development of specialized laser systems for these purposes is presently feasible. Continuous multipoint coherent acoustical systems for non-destructive penetration and measuring of blood flows is not presently available but the necessary technology is available and appears promising to perform exploratory and phase A feasibility studies.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

A,C) Non-surgical, non-destructive medical surveillance of the astronauts' cardiovascular systems, aerosol behavior within the Shuttle and the measuring of surface winds on solar bodies with atmospheres and accessibility for implantation of an instrument package are all of high scientific value and interest.

D) This technology advancement would need a phase A study followed by design and fabrication. Spin-offs to the private sector for all these systems could be tremendous in the areas of medical research and environmental safety.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Coherent Detection PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

At the present time there appears to be no suitable non-destructive, remote technique t~ perform the functions outlined in paragraphs 5 and 6.

8. TECHNICAL PROBLEMS:

1. Development of suitable trackers for signal tracking and analyses of laser systems would be required. (Trackers are presently available but would have to be modified and upgraded).

2. Suppression of surface noise would be required as well as development of a multichannel receiver for the acoustical system.

9. POTENTIAL ALTERNATIVES:

There appears to be no suitable alternative to perform the functions described in paragraphs 5 and 6.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The development of the above described systems is not presently funded. Advancement in the state of art will be slow if NASA expends no special effort in this area.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Coherent Laser Detection Technology

Coherent Acoustical Detection Technology

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Coherent Detection PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. Cliff, W. C., Laser and Acoustic Doppler Techniques for the Measurement of Fluid Velocities, NASA TMX-64932, May 1975.

2. Histand, M. B., Miller, C. W., McLeod, F. D., Transcutaneous Measurement of Blood Velocity Profile and Flow, Audiovascular Research, Vol. 7, 1973.

3. Cliff, W. C. and Huffaker, R. M., Application of a Single Laser Doppler System to the measurement of Atmospheric Winds, NASA TMX-64891, Oct. 1974

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Superconducting Instrumentation and Sensors PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: ______

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop superconducting quantum electronic instruments and circuit components for NASA applications: analog and digital devices; D.C. thru far IR; computer memories; et al.

4. CURRENT STATE OF ART: Generally as stated in the attached review paper by Kamper (IEEE Transactions on Magnetics, Vol MAG-11, No. 2, 1975).

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

A wide variety of important sensors, signal generators, mixers, digital devices, computer memory elements, magnetic shields, etc. have been suggested and many have been carried to the stage of practical application (e.g. Josephson Junction magnetometers are available commercially). They employ the Josephson effects, the properties of bulk superconductors, or both and operate with sensitivites, selectivities, efficiencies, and noise levels usually much better than their conventional counterparts. Their application in advanced scientific flight experiments will be required in many instances (mission driven) and desirable in others (opportunity driven).

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

To achieve required performance, many advanced scientific flight missions, such as gravitational, infrared, and cosmic radiation experiments, will be dependent on operation at temperatures of a few degrees Kelvin (dimensional stability, low noise) and on the use of superconductors (low magnetic fields, high sensitivity measurements, strong magnetic fields). Thus they will carry liquid helium cooling systems into space.

Consequently, in addition to primary experiment equipment (cryogenic gyro - scopes, infrared sensors, superconducting magnets) employing superconducting techniques (many of which still require considerable development), there will be an opportunity to utilize secondary electronic systems (communication devices, computer memories, and digital circuitry, on-board calibration standards) using superconductivity. NASA-OAST should actively pursue this development.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Superconducting Instrumentation and Sensors

7. TECHNOLOGY OPTIONS:

For many advanced scientific missions no options exist at present for primary sensors. Conventional techniques are often adequate for secondary apparatus. It will probably develop that for flight systems in which a liquid helium environment is available, some secondary superconducting devices will prove to be so superior to conventional ones that their use will be demanded.

8. TECHNICAL PROBLEMS:

Research is still in its youth. Many applications of value to NASA have been demonstrated on a laboratory basis but must be raised to a more mature application level. Others have already been made commercially successful. Some have only been suggested, and surely many ideas have not yet appeared.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Liquid helium refrigeration systems (closed loop refrigerators or open loop storage dewars) must be developed for space.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Superconducting Instrumentation and Sensors PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

CALENDAR YEAR

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

1. Kamper, R. A., "Review of Superconducting Electronics", IEEE Transactions on magnetics, Vol. Mag-11, March 1975, pg. 141.

2. Numerous papers on all aspects of applied superconductivity in the above referenced journal, which is devoted to the proceedings of the 1974 Applied Superconductivity Conference.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Plasma Probe PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Instrument

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure solar wind plasma parameters accurately beyond 8 astronomical units from sun.

4. CURRENT STATE OF ART: Solar wind plasma using current techniques has parameters, particularly heat flow, which are not as well determined as desired beyond 8 astronomical units from sun. HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Solar wind ions and electrons are energy analyzed to give solar wind plasma parameters: speed, flow direction, parallel and perpendicular temperatures, heat flow, and higher order moments of the velocity distribution.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Current plasma probes use electrostatic fields for energy analysis and electrometers or channel multipliers for detection.

b. To perform more accurate measurements beyond 8 astronomical units from the sun, new configurations of electrostatic fields and electrometers or particle detectors, or new methods of energy analysis and/or particle detection must be utilized.

TO BE CARRIED TO LEVEL 9

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Plasma Probe PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

A very large instrument, scaled up from those used closer to the sun than 8 astronomical units, could provide larger fluxes of solar wind particles to the detectors used.

8. TECHNICAL PROBLEMS:

In more general terms than the wording of Item 7 above, the decreased solar wind flux far from the sun must have accurate measurements made of moments of the velocity distribution with minimal instrument weight, power and special pointing requirement.

9. POTENTIAL ALTERNATIVES:

Use of a large, relatively heavy, scaled up instrument.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Instrument development and refinement work.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Energy/Velocity/Analysis of Charged Particles

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Plasma Probe PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Study Concepts of Instrument		—																	
2. Design Breadboard		—	—																
3. Fabricate Model for Test			—																
4. Laboratory Testing			—	—															
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

		TOTAL
TECHNOLOGY NEED DATE		
NUMBER OF LAUNCHES	No New Launches Planned.	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): Airborne Detector for Trace Radicals CLO, OH, O, in the Stratosphere PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Stratospheric Gas Analysis

3. OBJECTIVE/ADVANCEMENT REQUIRED: A technique to measure the minor trace radicals by using laser induced resonance fluorescence.

4. CURRENT STATE OF ART: Some successful laboratory experiments have demonstrated the probability of success.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

In pollution studies of stratosphere the radicals CLO, OH, and O occupy a position of critical importance because the catalytic reactions they partake in control the ozone radiation shield of the Earth. Measurements of O have been made in the upper stratosphere using resonance lamps and measurements of OH and CLO are being attempted in the near future using the same techniques. Initial research efforts on laser-induced resonance fluorescence techniques in the laboratory are in progress to identify appropriate spectral bands and prove feasiblity of the approach in the flight environment.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The laser is a spectrally pure tunable source of high intensity UV radiation, ideally suited to producing the resonance fluorescence spectra needed to make measurements of minor atmospheric constituents.

b. Interferences from competing resonances from differenct species are easily avoided because the laser can be tuned.

c. One laser and several photodetectors can be used to detect multiple species in the same instrument.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Airborne Detector PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Resonance lamps have been developed for O and OH. Efforts to develop a system using them.

8. TECHNICAL PROBLEMS:

No laser currently exists that is small enough or reliable enough for aircraft instrumentation.

9. POTENTIAL ALTERNATIVES:

Using individual sensors with resonance lamps if such can be developed for the species of interest.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The problem will not be solved without Government support because it has little immediate commercially beneficial output. NSF and NASA are the most likely agencies for controlling researchers in industry and academia.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Small, reliable portable tunable laser source for UV radiation.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Airborne Detector PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Background Measure.																			
3. Laser Development																			
4. Prototype System De.																			
5. Flight Development Test																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Improved Systems																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

"Detection of OH in the atmosphere using a Dye Laser" E. L. Baardses and R. W. Terhune, Applied Physics Letters, Vol. 21, No. 5, Sept. 1972.

"Measurement of Hydroxyl Concentration in Air Using A Tunable UV Laser Beam" Charles C. Wang and L. I. Davis, Jr., Physical Review Letters, Vol. 32, No.7, Feb. 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): IR Detector Silicon Surface Barrier Detector with Small Sensitive Volume (2x2x2)mm PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensor

3. OBJECTIVE/ADVANCEMENT REQUIRED: Prepare silicon surface barrier detector with approximately cubical sensitive volume and acceptably low noise and high resolution. Should be totally depleted.

4. CURRENT STATE OF ART: Silicon surface barrier detectors with sensitive volume of 2x5x5mm, totally depleted, with acceptable noise, smaller volume will have less noise.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

For simplest energetic trapped particle experiment for probes into outer planet atmospheres, an approximately cubical sensitive volume totally depleted silicon surface barrier detector would be required. This sensitive volume is readily available with lithium drifted silicon detectors which have been used for many years with such detectors in earth orbit. The outer planet atmosphere probe will require passive storage in space for at least two years and the lithium drifted detectors would require biasing during this time for reliable operation. Biasing would be difficult to provide in the probe. The surface barrier detectors would not require biasing.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☒ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The simplest energetic trapped particle experiment for probes into outer planet atmospheres requires a silicon detector with a large cubical volume.

b. Presently used detectors with these volumes are lithium drifted units.

c. For the two year minimum storage time required for outer planet atmosphere probes, reliable operation is not expected with unbiased lithium drifted detectors.

d. Surface barrier detectors if made with a totally depleted large sensitive volume and acceptable noise and resolution would be compatible with this experiment on outer planet atmosphere probes.

TO BE CARRIED TO LEVEL 6

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Silicon Surface Barrier IR Detector Detector with large cubical sensitive volume (2x2x2) mm

7. TECHNOLOGY OPTIONS:

Use a more complex energetic trapped particle experiment on outer planet atmosphere probes.

8. TECHNICAL PROBLEMS:

1. Increased weight and power of a more complicated experiment.
2. Means to supply bias voltage for a lithium drifted detector.

9. POTENTIAL ALTERNATIVES:

No assurance of correct operation of required size of lithium drifted silicon detector after more than two years of unbiased storage.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

General energetic particle detector technology.

NO.

DEFINITION OF TECHNOLOGY REQUIREMENT

PAGE 3 OF 3

1. TECHNOLOGY REQUIREMENT (TITLE): Silicon Surface Barrier IR Detector
Detector with large cubical sensitive volume (2x2x2) mm

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Detector Design		—																	
2. Detector Fabrication		—																	
3. Detector Lab-Checkout		—	—																
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

CALENDAR YEAR

13. USAGE SCHEDULE:																		TOTAL
TECHNOLOGY NEED DATE							Δ											2
NUMBER OF LAUNCHES						1	1											

14. REFERENCES:

Outer planet atmospheric entry probe-system description, July, 1975, NASA-AMES Research Center.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.